



The Blast Furnace and Steel Plant

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The Blast Furnace *and* Steel Plant

Vol. X

PITTSBURGH, PA., OCTOBER, 1922

No. 10

Bases of Modern Blast Furnace Practice

Outline of Bases Upon Which Modern Blast Furnace Practice Has Been Built Up—Shows How Adoption of These Methods Lead to a Desirable Improvement Both Regarding Economy and Output.

By A. K. REESE

BEFORE discussing these prime factors in detail, it might be as well to consider the objects which modern blast furnace practice seeks to obtain. That practice is distinctly the result of evolutionary progress, the modern phase dating from 1894, when James Gayley introduced the low bosh at Braddock, Pa.—up to the present, the era of the large hearth diameter and steep bosh angle.

There are three principal objects in all blast furnace practice ranking in importance in the following order—quality, economy and quantity. The first is essential. The second is commercially of great importance. The third is highly desirable, particularly in its bearing upon the second. No. 1 may be obtained independently of the other two. No. 2 may be obtained, to a degree, independently of No. 3. No. 3 is, to a degree, subject to Nos. 1 and 2. In all blast furnaces one of these objects has been the limiting factor in the attainment of the others.

The object sought through the application of so-called modern practice may be described thus:

Consistent with quality to produce the greatest possible economical quantity, and as any material increase in quantity has a direct and favorable bearing upon economy this description of the object of modern blast furnace practice may be condensed to—*the attainment of the greatest possible quantity consistent with quality.*

The degree to which this object has been attained in certain localities, in comparatively recent years, resulting in normal economical outputs of from 400 tons to 600 tons per 24 hours, is well known, and demonstrates the great commercial advantage to be obtained by the adoption of the principles and methods by which it has been attained, in those other localities which up to the present have not yet fully adopted them.

There may be, and doubtless are, some makers who are still of opinion that with their particular materials the principles and methods of so-called modern blast furnace practice are not applicable. It is with the hope of convincing them, and of strengthening the growing belief of others, that the author has undertaken this paper, for

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it is his firm conviction that those principles and methods are adaptable to any iron bearing materials which are workable in a blast furnace, subject of course, to suitable fuel and flux being obtainable within even a wide degree of quality, and subject, likewise, to a minimum degree of variation in that quality for any individual operation. He feels convinced that their adoption will lead to so great an advantage as to constitute almost a revolution in the pig iron industry in those localities where they have not hitherto been applied.

The four prime factors above referred to are:

1. Preparation of Materials.
2. Furnace Design.
3. Auxiliary Equipment.
4. Method of Operation.

Preparation of Materials.

That the mechanical and physical conditions of the materials charged into a blast furnace have a most important bearing upon its successful and satisfactory operation, affecting both its operative conditions and the economy of the results obtained therefrom, is a fact which no blast furnace operator is likely to dispute, but while it is true of any blast furnace it is particularly true in its bearing upon the operation of the modern blast furnace. One of the essential conditions of satisfactory operation is that there shall be as nearly as possible uniformity of chemical reactions, and of physical movement of the materials throughout the whole cross-section in every zone of the furnace. Two elements are required to obtain this in theoretic perfection, namely, perfect uniformity in the size and density of the materials charged, and a sufficient blast volume to produce the condition of a plenum throughout the whole furnace interior. While it is, of course, impracticable to obtain for blast furnace use materials of perfectly uniform size and density in each of the three classes of materials used in pig iron smelting—fuel, flux and ore—it is practicable to approximate to a degree to that condition by the use of proper means for their preparation.

It is obvious that the feature which most directly bears upon the essential condition above mentioned is that of distribution, and in order to obtain as nearly as practicable uniformity of distribution such preparation

as will give as nearly as practicable uniformity of size must be resorted to. For reasons which will be referred to later, uniformity of size only is not, however, sufficient; for example, uniformly large size, while giving uniformity of distribution, would be detrimental to economical operation. The preparation of materials must be in the direction of uniformly small size.

Fuel (Coke).—While this principle is much more important in its application to the ore and flux than to the fuel, it also applies, to a degree, to the latter. As rapidity of action is largely dependent upon rapidity of combustion of the fuel, it is desirable that the fuel should not be charged in lumps of excessive size, and preferably should not exceed 4 inches to 6 inches. This is, of course, assuming that the coke is of proper physical condition. It may be said here that the physical quality and chemical purity of coke for blast furnace use are of the greatest importance. It should be strong, but of not great density, and as low as possible in ash and sulphur. There is nothing which more greatly interferes with the regular and economical operation of a blast furnace than soft, friable, or high ash coke, as everyone connected with the industry has experienced during late years under the conditions existing during, and for some time after, the late war. The disadvantage of high sulphur in the coke need not be emphasized.

The coke as charged into the furnace should be thoroughly screened to free it from smalls, commonly known as breeze, and should be of sufficient strength to prevent the excessive formation of smalls in the furnace through the crushing effect of the burden. The strength should not, however, be of the kind which is produced by great density which destroys the cellular structure. A dense coke burns slowly and is, therefore, inimical to rapid combustion, which is necessary for fast driving, whereas cellular structure permits the heat and the agents of combustion to penetrate readily to the interior of the lumps, thus facilitating combustion. On the other hand, a very open cellular structure produced at the expense of strength is equally to be avoided as tending to produce smalls through its lack of resistance to crushing by the weight it has to bear, and abrasion by its movement in the furnace. Such a fuel is also subject to excessive waste in the upper regions of the furnace before it reaches the zone of its usefulness, owing to the greatly increased reaction upon it of the CO_2 in the gases— $\text{CO}_2 + \text{C} = 2\text{CO}$. It is, therefore, of the greatest importance in modern blast furnace practice that coke makers should give the greatest possible attention to the production of a coke combining these two essential features—strength and porosity. There are a number of factors entering into this problem of blast furnace coke making, by the careful study of which the makers may arrive at the production of coke having the desired physical properties described above. Some of these are the coal mixture, the mechanical condition of the coal as charged and its compactness in the oven, the oven temperature, the rate of carbonization, and uniformity of coking action throughout the coking chamber. It would seem hardly necessary to mention the great importance of chemical purity in the coke, as naturally the higher its carbon content the greater its efficiency. It is surprising, however, how much coke is produced with high ash and sulphur content for blast furnace use; in many cases, undoubtedly, the result of insufficient or inefficient washing of the coal, or insufficient attention to the selection of the coal for the production of blast furnace coke. Care in selection and efficient washing of coal for coke production are, therefore, of very great importance in their

bearing upon economical blast furnace operations, and every possible effort should be made by blast furnace owners to induce coke makers to meet their requirements as to mechanical, physical and chemical quality. It is the carbon which does the work in the furnace, and every decrease in the percentage of ash increases the available carbon and tends in other ways towards a higher degree of efficiency. In addition to the higher fuel value of low ash coke, it is lighter in weight, requires less limestone for fluxing the ash, and a lower amount of the fuel charged is required for forming and melting the slag produced from the coke ash. It is estimated that the formation and melting of blast furnace slag requires approximately 25 per cent of its weight in fuel, therefore, for every cwt. of slag produced from coke ash $\frac{1}{4}$ cwt. of fuel is lost so far as the smelting of iron ore—the primary object of the blast furnace process—is concerned.

Iron Ore.—From the standpoint of preparation, the iron ore is the most important of all the materials charged into the blast furnace, owing to the extremes in mechanical condition, from fines to large lumps, in which most iron ores are received from the mines, and the great variety of physical characteristics in different ores. The operation of the blast furnace is much more usually affected, for good or ill, by the mechanical condition of the iron ore than that of either fuel or flux. It is, therefore, of prime importance that this condition should receive very careful attention and whatever steps are necessary should be taken, in the way of preparation, to convert it to that condition—or as near to it as is practicable—as will insure the most beneficial effect upon furnace operation.

There are two principal features directly affected by the condition of the iron ore, both bearing upon the rate of production and upon economy. These are reducibility and distribution. The degree of reducibility of an iron ore depends primarily upon its density, a characteristic which in itself is not readily altered, except with dense ores containing high percentages of protoxide of iron (magnetite), the reducibility of which may be increased by subjecting them to a roasting process in an oxidizing atmosphere, thus converting the protoxide to peroxide of iron.

Rough Ores.—The rate of reduction in the furnace may, however, be materially increased for any particular ore containing lumps, whatever its degree of density, by increasing the surface area exposed to the action of the reducing agents. The obvious method of attaining this increase in surface area is by breaking the lumps into a number of smaller pieces. The extent to which this operation may be carried is, of course, limited by the cost of breaking the ore (a commercial consideration), and the tendency of any particular ore to produce an excessive proportion of fines in the breaking. The latter tendency, however, really does not exist to any considerable extent in ores whose condition allows of their being broken at all, for whatever smalls may be produced in the breaking are usually of sufficient size not to be classed as fines and may, therefore, be safely charged into the furnace with the larger products of the breaking operation.

The increase in the rate of reduction obtained by thus increasing the surface area exposed to the agents of reduction in the furnace has, in addition to the higher possible rate of production, a very important effect upon economy of production. There are two principal reducing agents in the blast furnace process, carbonic oxide

and solid carbon, and it is generally accepted that reduction of iron oxide by carbonic oxide, in the upper zones, is a much more economical reaction than the reduction of iron oxide by solid carbon in the lower zones. It is, therefore, highly desirable that the whole or the greatest possible portion of the iron oxide should be reduced by carbonic oxide gas, and that this reduction should be completed before any lumps of iron oxide have reached the zone where conditions permit, in excess, the uneconomical reaction between them and solid carbon. It is obvious that the surest way of attaining this is to so increase the possible rate of reduction of the ore by increasing its surface area, as described above, that the maximum reduction may be effected by the carbonic oxide gas in the upper zones of the furnace. If this precaution of increasing the surface area by breaking the lumps of ore before charging into the furnace is neglected, the larger unbroken lumps will escape thorough reduction by carbonic oxide gas with consequent waste of fuel, particularly if any attempt be made to increase materially the rate of production by rapid driving. To obtain a high rate of production, with economy and quality, it is therefore necessary to prepare the ores in the manner described.

The degree to which it is commercially practicable to crush an ore depends upon its density. Experience has indicated that all ores should be crushed to sizes not exceeding such as will pass through a 3-in. or 4-in. ring, although ores of great density may be advantageously crushed to even smaller sizes. The standard of 3 or 4 in., which seems rather small for ores of a high degree of reducibility—the so-called “soft” ores—is not determined wholly from the standpoint of degree of reducibility, but also by its bearing upon distribution.

The question of the distribution of ore in a blast furnace is of the highest importance in its bearing upon regularity of operation, this in turn affecting most vitally the economy, quality and output.

This question has been referred to above in a general way in connection with uniformity of action in the furnace, but important as that is as regards all the materials, solid and gaseous, entering into the blast furnace operation, the distribution of the ore is the most important consideration in regard to the solid materials.

In the consideration of this question it is necessary to keep in mind the great essential—*equality of action throughout the whole of every cross section of the furnace interior*. Except for the fact that the operations are taking place in a vertical shaft of circular cross section, this result would be obtained, theoretically, only with materials of exact uniformity in size and density, but the fact just mentioned introduces a feature which interferes with this theoretical requirement. It is a well known fact that the gases have a natural tendency to ascend next to the walls and would do so to the neglect of the interior if the furnace were filled with materials of exact uniformity in size and density. It is necessary, therefore, in order to secure approximate equality of action, to have a somewhat greater resistance to the passage of the gases in the materials nearest the walls than in the interior. It is to this condition that the ordinary bell and hopper charging apparatus owes its satisfactory use, discharging the materials as it does in such a way that a greater proportion of the smaller particles remains next to the walls, thus providing the somewhat greater resistance to the ascending gases required there. In order that this distribution by bell and hopper charging may give the desired result the relation of the diame-

ter of the bell to the diameter of the furnace throat at the stock line is of material importance, as likewise that the falling materials shall first strike the materials in the furnace, when nearly full, at about 18 in. from the walls. The former relation is usually a bell diameter 4 to 5 ft. less than the throat diameter at the stock line. The bell angle is usually 40 deg. to 45 deg., and in some cases 50 deg.

This method of charging results in the surface of the material in the furnace assuming the shape of an inverted cone with its base about 18 in. from the walls, from which point they slope away slightly to the surface of the walls. The smallest particles lie on the base of the cone, and between it and the walls, together with a portion of the smaller lumps and rubble. The inner slope from the base to the apex of the cone consists of pieces of gradually increasing size with practically only the largest lumps at and near the apex. This description does not, of course, apply to an ore mixture consisting of all fines, or of lumps of uniform size, conditions which very seldom exist in blast furnace practice, but it does apply to the usual run of ores which consist of a mixture of fines, rubble, and lumps.

It is obvious that the greater the difference between the largest and the smallest pieces, or, in other words, the larger the lumps the greater the sorting action above described, and conversely, the smaller the maximum size of the lumps the less the degree of segregation. It is, therefore, further obvious that to avoid excessive segregation, the preparation of the ore by crushing the lumps to smaller, say rubble, size is necessary. The crushing of the lumps prevents excessive segregation in two ways, first, being smaller, they have less tendency to roll down the sides of the inverted cone to the apex and, secondly, the broken pieces have usually sharp and jagged edges, and have, therefore, a greater tendency to lodge nearer where they fall, and the movement of the materials to the center is more likely to be *en masse*, carrying a certain amount of smalls with it. It is thus that preparation by crushing materially improves distribution by preventing excessive segregation, which is a condition directly inimical to the application of modern blast furnace practice.

In the distribution existing when the usual run of ores and limestone are charged “as received,” there is, as described above, a core, or column in the center of the furnace consisting almost entirely of the largest lumps, the area of the cross section of this core varying between the size and proportion of lumps to rubble and fines. Between this core and the walls there is an annual ring consisting of a mixture of rubble and smalls, in which the proportion of rubble to smalls gradually decreases until, next to the walls, there are practically only smalls and fines. As previously pointed out, an essential to regular and economical descent of the materials is perfect uniformity of action of the ascending gases upon the whole of every cross section of the material in the furnace, and while this is an ideal condition which may be impossible of full attainment in actual practice, the nearest possible approach to it is of the greatest importance. There can be very little approach to such a condition if the ascending gases are forced, under pressure, through a mass of materials distributed as just described. Very little, if any, of the gases will find contact with the closely packed fine materials close to the walls, and the greater proportion will pass up through the more open structure in the center, the core of large lumps, and a proportion only through the annual ring of rubble and smalls. The result of this unequal distribution of the ascending gases is the faster descent of the

largest lumps in the center, and a gradually slower descent of the outlying materials. Such a descending movement of the materials of the various sizes is exactly contrary to what is most desirable. Those which descend most rapidly, owing to their slower rate of reducibility should descend most slowly, and those which descend most slowly, owing to their high rate of reducibility should descend most rapidly. Maximum economy and output are impossible under such conditions, for, apart from the question of irregularity of movement which almost always results from them (see below), it is necessary to provide an excess of fuel to insure the complete reduction of the more rapidly descending lumps before they enter the melting zone (see above, under Reducibility), and the rate of driving is limited by their slower rate of reducibility. Any attempt at really fast driving under these conditions so reduces the ratio of ore to fuel which can be carried that not only is the output not increased, but the fuel consumption is very greatly increased, with the added danger of the production of low grade iron through unreduced ore entering the furnace hearth from over driving, or irregular descent of the materials.

Under the conditions existing in a furnace charged in the manner under consideration, there is always a strong tendency towards irregularity of movement, or none at all, in the material nearest the walls, with a gradual building up on the walls. This building up continues until portions either become permanently stationary, forming scaffolds, or masses break away and are precipitated towards the center and into the actively descending materials and rapidly ascending gases, constituting the well known slip. This procedure is more or less frequent and more or less severe, from the small slip, causing temporary production of off grade iron, to the heavy slip or explosion, which either blows off the furnace top, or fills the tuyeres with slag, chills the hearth, "gobbs up" the furnace and puts it out of commission for days, an evil too well known among those who may be interested in this paper to require any emphasis; but to whatever degree it occurs it very seriously interferes with the regularity which is essential to the best results. The disadvantages from the accumulated effects of these conditions are only avoided, and even then not always satisfactorily, by periodical partial clearance of the furnace walls by the use, temporarily, of considerably reduced burdens, or, which is the same thing, by charging extra fuel, at the expense of both economy and output. These evils can only be avoided by the proper preparation of lump ores by crushing.

Fines Ores.—The disturbing effects upon blast furnace operations of the use of any considerable proportion of very fine ores—exaggerating the conditions described under Distribution—are too well known to require special emphasis. Although in modern practice furnace design and method of operation have considerably reduced these effects, such ores are still sufficiently objectionable in this respect to make advisable some treatment to change their character as fines. In this case the process of preparation is the reverse of that for lumpy ores, that is, instead of reducing, it is desirable to increase their size, in order to remove their clogging effect in the furnace, and to prevent their being carried out in excessive quantities, by the escaping gases, into the gas flues.

Various processes have been introduced for this purpose, such as briquetting, nodulizing, and sintering, each of which yields a satisfactory product for use in the blast furnace. Sintering is the more recent process, and has grown very rapidly in favor, owing to its lower production costs, and the large range of materials which

may be treated by it, including blast furnace flue dust, the recovery of which alone in some cases warrants the installation of the process, particularly as, in addition to the iron ore recovered, the dust usually carries such an excess of fuel over what is required for its own treatment that a considerable proportion of other fine ore, without fuel, may be mixed and sintered with it. By these processes, and particularly sintering, many ores which, in their natural state, are unsuitable for use in the blast furnace, either owing to their mechanical condition, or high sulphur content, or both, may be rendered suitable.

The Flux (Limestone or Dolomite).—Of the solid materials, the flux, being easily acted upon by the heat and chemical reactions, and usually forming a small proportion of the mixture, is of less importance in connection with the question of preparation of materials. It is of sufficient importance, however, to receive consideration, as its mechanical condition has a definite bearing both upon distribution and rapidity of action in their bearing on economy. Although the effect is less in degree, it is the same in principle as in the case of the ore, and for similar reasons the flux should be broken to as nearly as practicable uniform size. In practice it has been found sufficient to break it to sizes not exceeding 4 in. or 6 in., or such as would pass through a 4-in. or 6-in. ring, although there is no disadvantage in breaking it to even smaller sizes. The author has had personal experience with large blast furnaces using oyster shells alone as flux over a considerable period with perfectly satisfactory results, except that there was added to the waste gases a further objectionable feature to their usual asphyxiating qualities, their bad odor.

Blast.—The only remaining "raw material" essentially used in blast furnace operation is the air which supplies the oxygen necessary for the combustion of the fuel.

There is little to be said with regard to the blast under the heading of Preparation of Materials, that is, in its bearing upon modern blast furnace practice as distinguished from practice which is not "modern," except that the usual custom in the latter is to take the air as we find it, although not always in all its purity. Too little attention is usually paid to this point. Natural air in its purest state has its detrimental constituents, but as a rule little attempt is made to draw the supply for the blowing engines even as pure as it occurs. The proximity of boilers and free exhaust auxiliary machinery, and various sources of evaporation, too often charge the air near blast engine houses with quantities of moisture much in excess of that in natural air "in its purest state." In modern practice practically all exhaust steam is condensed, and a large proportion of the auxiliary machinery is electrically driven. There is, therefore, little, if any, opportunity for extraneous moisture to enter the blast engines with natural air. This is a feature of considerable importance, and has an appreciable bearing upon the economy of modern practice.

Although in view of its lack of more general adoption it has no direct bearing upon the subject of this paper there is a treatment to which natural air may be subjected for its improvement for blast furnace purposes, which comes logically under the heading of Preparation of Materials. As a strong advocate of this treatment the author hopes that a discussion of it at this point will not be considered out of place. This is the question of dry blast, or, to be more exact, the treatment of natural air for reducing its hygroscopic moisture to a uni-

form and low content—a treatment first introduced and practically demonstrated by James Gayley in 1904.

There has been a great deal of discussion, and even contention (mainly theoretical) as to the merits of this process. At the time of its introduction a great stir was caused in iron-producing centers, and during the following years a considerable number of plants were installed for its use in the United States more particularly, and in Europe. Some of these installations are still used continuously, and some are used intermittently in the United States, that is, they are used in the summer months when the moisture content of the air is high, and discontinued in the winter months when the moisture is naturally low. In other cases their use has been entirely discontinued.

There is, however, practically unanimous agreement amongst those who have used "dry blast" that its use does improve blast furnace results, although opinions differ as to the degree of the economy. The author has had an opportunity during the past 18 months of discussing this matter with representative American blast furnace operators, particularly as to the reasons why the process has not been more generally adopted and its use continued more generally where plants have been installed. The explanation given is that the benefits obtainable from "dry blast" have been superseded by the great advance in blast furnace results brought about in recent years by improvements in furnace design, and the altered practice following those improvements. In other words, it has been possible to obtain, in other ways, advantages equal to those derivable from "dry blast" under the older practice. It may be a very bold thing for the author to say in the face of these opinions, but he believes that attitude to be a mistaken one, and that if every advantage which can be derived from "dry blast" is provided for, further improved results are obtainable in addition to those already obtained by the means above referred to.

The author has had considerable experience with "dry blast," having used it continuously on two large furnaces during the past 13 years with such satisfactory results that he would have considered its abandonment a very serious step in the wrong direction. It is not his intention to enter here into a discussion upon the advantages of "dry blast" in detail or in general, but there is one very important feature in connection with its use which seems to have been missed by those who have used and abandoned it, either partially or wholly, a feature which, in all probability, explains the attitude adopted towards it in the United States in conjunction with later American practice, and possibly elsewhere. This is the important factor of blast temperature. It is the author's experience, and he believes it is also general experience (although there may be isolated cases to the contrary), that with natural air there is an upper limit to the temperature of the blast which can be used with satisfactory and smooth working for any particular furnace. Any considerable increase beyond this limit causes "stickiness," "hanging," and irregular movement of the materials in the furnace. In his discussions with American blast furnacemen he was told that this was the case even with furnaces of the latest design, and a particular case was cited at one of the most modern plants in America, where very high temperatures of blast were tried with results as above mentioned. The blast temperatures generally used range from 1150 deg. F. to 1250 deg. F., while with clean gas and modern stove design (and sufficient stove capacity), temperatures as high as 1500 deg. F. to 1600 deg. F. are obtainable.

The economical advantage which could be derived were it possible to make satisfactory use of this addi-

tional heat in the blast, need hardly be emphasized, and any practicable means which would render this possible would confer a very important boon upon the iron producing industry. The author's experience is that such a means is available in "dry blast," and that it is this further advantage of dry blast added to those which are already conceded it, which would, if taken advantage of, settle the doubts of those who are still undecided, and convert those who have already condemned it. It may be said that he was in a fortunate position to have available such high temperatures (he has used temperatures as high as 1600 deg. F., normally from 1450 deg. to 1550 deg. F., temperatures under 1400 deg. F. being considered too low), but what was available to him is obtainable by others, and he would emphasize the fact that without dry blast, although available, he could not have used them.

(To be continued.)

ELECTROCHEMISTS STUDY ELECTRIC HEAT

Electric heating, a matter of particular importance at the present time, was one of the leading subjects discussed at the forty-second annual convention of the American Electrochemical society, held at the Windsor Hotel, Montreal, September 21-23. More than 200 delegates and members of other scientific societies attended. President C. G. Schulerberg of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., served as chairman. Addresses of welcome were delivered by Alderman Seybold representing the city, and Dr. R. F. Ruttan of McGill University, on behalf of the scientist of Montreal.

DR. STANSFIELD TO ADDRESS ELECTRICAL ENGINEERS

Prof. Alfred Stansfield, D. Sc. Associate of the Royal School of Mines; Fellow of the Royal Society of Canada, Birks Professor of Metallurgy in McGill University, Montreal, will speak on "Electric Smelting of Iron Ores" before the Cleveland District section of the Association of Iron and Steel Electrical Engineers Monday, October 9, 1922, at the Hotel Winton, 6:30 P. M.

In 1907 Prof. Stansfield, published his first book "The Electric Furnace," but on account of the very rapid development of the art, it has been necessary to make revision whereby the second edition has been placed at the disposal of the engineering profession.

Anyone who has read Prof. Stansfield's books cannot help but be impressed with the thoroughness of treatment of the various subjects relative to electric smelting. It is felt that, since the Professor is coming to Cleveland now with the last word on the subject of Electric Smelting of Iron Ores, which he will illustrate with lantern slides, that the Electrical and Metallurgical Profession of Cleveland has been highly honored. This is an open meeting and everyone is invited.

BRICKS FROM DOLOMITE

At the Columbus, Ohio, ceramic experiment station, the Bureau of Mines has made standard sized bricks from calcined dolomite and from raw dolomite, using 10 per cent of the flux Fe_2O_3 , Al_2O_3 , SiO_2 . Calcined dolomite was found undesirable for making into bricks, as the mud slakes so rapidly, and all samples cracked badly on account of enormous shrinkage during drying and burning. Raw dolomite, together with 10 per cent flux, gives excellent promise.

Corrosion Control by Deactivation of Water

Relative Rate of Corrosion—Protective Coatings—Dissolved Oxygen in Water—Oxygen Removal by Chemical Means.

By FRANK N. SPELLER, B.A.Sc., Member A. S. M. E.

PART I

REPLACEMENTS made necessary due to corrosion of iron and steel in this country have been estimated to run over 1,000,000 tons per annum. While this is perhaps little better than a guess, it is probably not overstating the facts. Much of this loss occurs in piping, boilers and other closed systems. For example, a large modern building contains over 200 miles of piping of all kinds. There are the arteries of the structure, which are both difficult and expensive to replace. The hot-water piping is most subject to attack, frequently lasting less than 10 years under modern conditions.

One of the most fruitful means for effecting economy is through the elimination of waste. The subject of this paper deals particularly with the conservation of iron and steel in contact with water in closed systems, but it may be well to first outline briefly some of the important facts and principles relating to corrosion in general.

The Electrolytic Theory of Corrosion has been stated in various terms in a number of articles which may be referred to by those who are particularly interested in this phase of the subject.[†] The essential reactions are: The action of hydrogen ions in water which results in the solution of iron; the concentration of hydrogen ions, acidity of solution; the polarization of the metallic surface by deposition of hydrogen which protects the metal from further attack; the retarding effect of ferrous hydrate in solution; and the removal of deposited hydrogen and ferrous hydrate by oxygen in solution in water. Without the last reaction, corrosion cannot proceed to any appreciable extent, except in rare cases where a high hydrogen ion concentration is maintained, as where water contains magnesium chloride. In this case the water when heated brings about the following reaction: $\text{MgCl}_2 + 2\text{H}_2\text{O} = \text{Mg}(\text{OH})_2 + 2\text{HCl}$. In contact with iron, ferrous chloride is then formed, which is hydrolyzed by water ($\text{FeCl}_2 + 2\text{H}_2\text{O} = \text{Fe}(\text{OH})_2 + 2\text{HCl}$). These reactions are cyclic and will continue in the presence of free oxygen, which disturbs the equilibrium of the last reaction by formation of insoluble ferric hydrate ($4\text{Fe}(\text{OH})_2 + \text{O}_2 + 2\text{H}_2\text{O} = 4\text{Fe}(\text{OH})_3$).

In most cases the amount of free oxygen available determines the amount and character of corrosion. It is therefore convenient to divide corrosion of iron into three broad classes:

1. **Atmospheric corrosion**, where oxygen is available in large excess.

2. **Underwater corrosion**, where the amount of oxygen present is limited to the solubility of that gas in water.

3. **Soil corrosion**, in which the ratio of moisture to available oxygen varies considerably but where the influence of contact of the metal with dissimilar materials and different electrolytes is likely to be an important factor in accelerating corrosion. This has no reference to the influence of electrolysis from stray electric currents *per se*, which is another problem.[‡]

In this paper the author confines the discussion to the second of these three classes, which includes broadly, corrosion of the interior of pipes, tanks, economizers, boilers and other closed water systems which form such an important part of building, and power plant construction. Before discussing the practical solution of this problem, it may be well to refer briefly to the main factors which influence corrosion.

External Factors.

The main factors which control the rate and distribution of corrosion of iron in water (and this applies, generally speaking, to brass and some other metals) are given below in order of importance:

- (a) Amount of oxygen in solution.
- (b) Temperature.
- (c) Quantity and velocity of flow.
- (d) Quality of water; presence of one or more electrolytes in solution.
- (e) Contact with electro-negative material.

Irregular corrosion, known as pitting, is brought about by contact of the metal with electro-negative materials such as mill scale, brass, copper, but in the absence of free oxygen the influence of all other factors mentioned is insignificant, except where acid is generated continuously, in which case there will be some solution of iron but much less where free oxygen is not present.

Composition of Material.

Before discussing what has been done and what may still be accomplished to conserve such material, it is in order perhaps to answer the question: What may be expected from special treatment of the metal, or what has been done towards the production of a non-corrosive metal suitable for such conditions? A large amount of thought and work has been devoted to this field by metallurgists with some results of note

[‡]Report of Committee on Electrolysis, 1921, Am. Inst. of Electrical Engrs.

*Communicated by the author to the Franklin Institute.

[†]"Corrosion of Steel," A. S. Cushman: J. of Franklin Inst., 165, III, 1908. "Corrosion of Iron and Steel," W. H. Walker: I. Am. Chem. Soc., 29, 1251; 30, 473, 1907. "Preservation of Hot Water Supply Pipe," Speller and Knowland: Trans. A. S. of H. and V. Engineers, vol. 24, 1918.

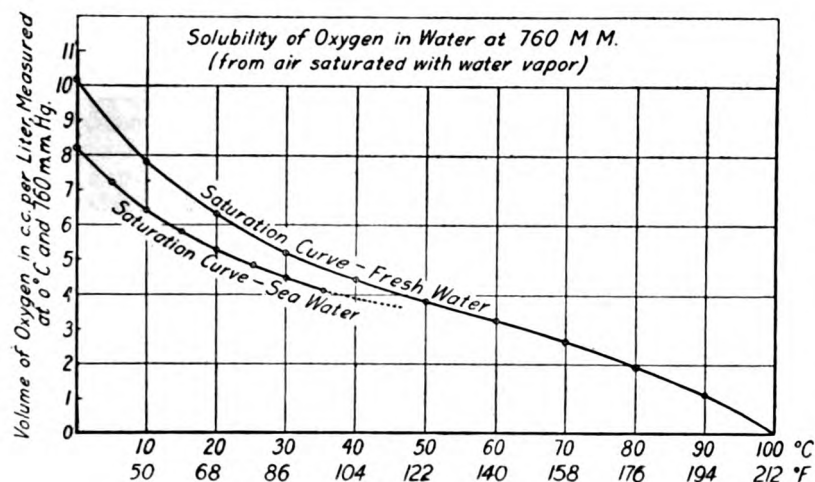


Fig. 1.

in the manufacture of special alloys such as monel metal, dur-iron, stellite, stainless steel (high-chrome steel), and other alloys, all of which, due to their non-rusting qualities, have useful fields. However, the use of these alloys is unfortunately limited by their high cost and the fact that such metals have not as yet been successfully fabricated for general purposes. So that we must still use such well-known material as zinc, tinplate, brass, copper, wrought iron and steel (uncoated or galvanized) and for most purposes for economic reasons, the choice is usually confined to the last two mentioned. Steel carrying 0.25 per cent copper has proved much better than non-copper bearing steel under atmospheric corrosion, but unfortunately has shown no superiority underwater or underground.

Relative Rate of Corrosion.

In passing, it may be useful to refer to a few of the many comparative tests of wrought iron and steel in water lines which have been made in recent years, for opinions are still somewhat divided in certain quarters on this question.

The author has previously summarized some of the practical information from experience and tests in serv-

ice on wrought iron and steel pipe in a paper before the International Association for Testing Materials—1912. Since that time considerable data have been collected from various sources which are summarized in Table I. An extensive series of tests in acid mine water was reported on by Committee A5—A.S.T.M., 1921*. The conclusion reached is practically the same from all these investigations, viz., that under water the origin and composition of iron makes comparatively little difference in the rate of character of corrosion. Whatever the influence of composition may be it is apparently small compared with the marked influence of variations in surface finish of the metal, internal strain, contact with other materials which are relatively more electro-negative in character, to say nothing of the predominating influence of other external factors referred to above which, after all, have most to do with controlling the rate of corrosion.

Enough has been said to indicate that at present in many cases, we have no choice but to consider means for keeping the water from contact with the metal or to remove the corrosive power of water and thereby render it inactive. Thus corrosion may be prevented or greatly retarded either by means of protective coatings or by removing the free oxygen from water.

Protective Coatings.

Many protective coatings have been devised to protect pipes and other metallic structures under water. These may be divided into (a) non-metallic coatings such as paints and bituminous dips, (b) metallic coatings. The latter may be classified into metallic coatings which are electro-negative to iron and those which are electro-positive. The former include lead, tin, copper, nickel, and protect only so long as the coating is intact, after which the coating metal usually accelerates corrosion and results in pitting. Electro-positive metals include such as zinc, aluminum and certain kinds of brass. Iron is protected by such metals, even though the protective coating does not entirely cover the sur-

*Proc. A. S. T. M., vol. 21, p. 157, 1921.

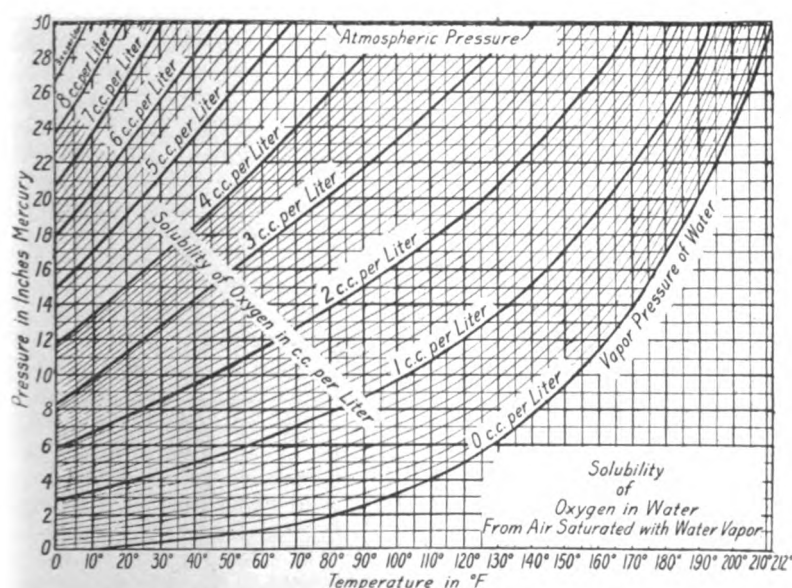


Fig. 2.

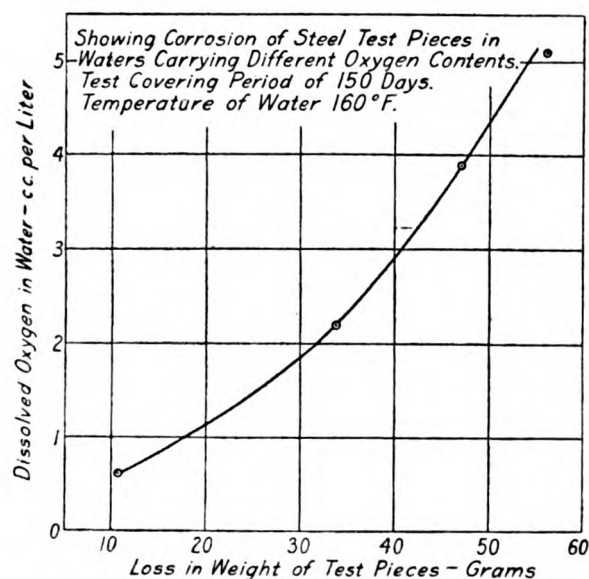


Fig. 3.

face, until the area of iron exposed becomes so large as to extend outside the range of galvanic influence of the more electro-positive metal. Zinc coatings on account of their economy and ease of application are most generally used and find a wide and useful application in various forms such as hot galvanizing, electro-galvanizing, Sherardizing and spraying. Each of these methods of zinc coating has special advantages for certain purposes which have been developed by experience.†

There is good evidence that iron and steel acquire under certain conditions a protective film or scale which often has considerable influence in warding off the attack of hydrogen ions in water. Iron or steel which contains over 0.10 per cent copper has a very decided tendency to develop a strongly adhering and more or less impervious coating of rust under atmospheric corrosion, but under water this metal corrodes like non-copper bearing steel, evidently because the rust formed under these conditions does not adhere so well and is more open in its physical structure. Steam pipes which have been in use for many years often exhibit such coatings, particularly where the steam carries a small amount of oil, which results in a protective coating consisting of a mixture of hydroxides of iron and certain oily deposits. The absence of this coating in modern systems fed by steam generated and delivered directly for heating purposes has in some cases resulted in more corrosion than where exhaust steam was previously used. The remedy for this is to reduce the free oxygen and carbonic acid in the boiler make-up water to a minimum, and keep the system tight as far as possible.

Waters of certain compositions throw down a protective deposit of organic or inorganic material on the inside surface of pipe, which has a marked effect in retarding corrosion. It has been observed that some of the domestic waters of New England are more corrosive since filtration has come into more general use.

Another instance of natural scale forming is found where water from the Great Lakes is heated for domestic use or power purposes. A thin scale is usually found on the inside of pipes which carry this water:

†Bureau of Standards Circular No. 80, "Protective Metallic Coatings for Rust-proofing of Iron and Steel," October, 1919.

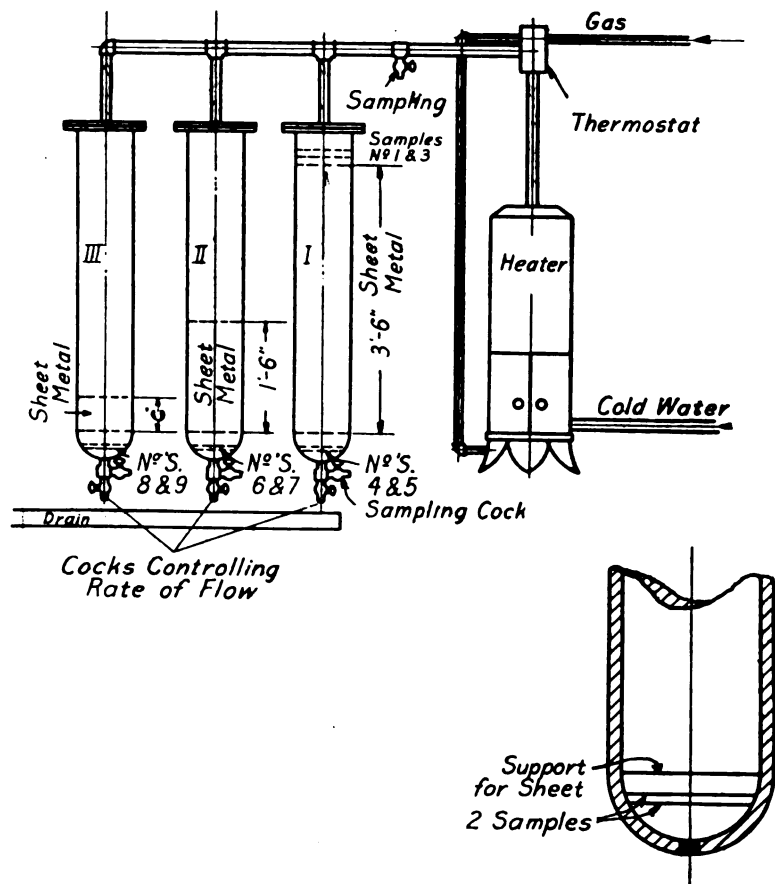


Fig. 4.

Space occupied by sheet metal (26 gauge). Tank No. 1, 33,500 c.c.; No. 2, 14,366 c.c.; No. 3, 4,790 c.c.

the average of several analyses of such scales collected by the author gave:

Iron	28.4 per cent
Lime, CaCO_3	3.0 per cent
Silica	4.8 per cent

The lime and magnesia are usually present as bicarbonates in these waters, and when heated a portion of the half-bound CO_2 is removed, resulting in precipitation of some of the lime. The silica found in these scales is probably precipitated by reaction with colloid

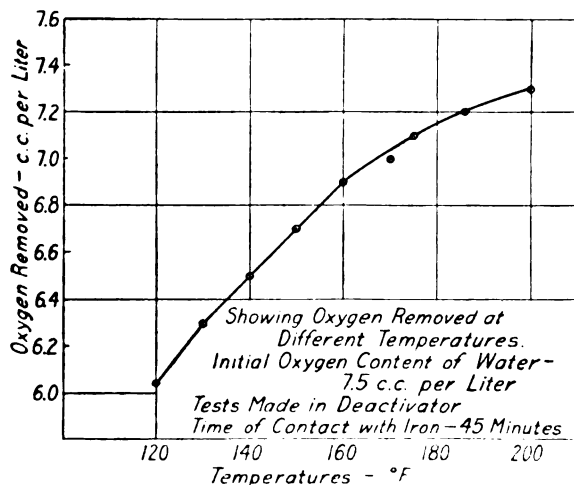


Fig. 5.

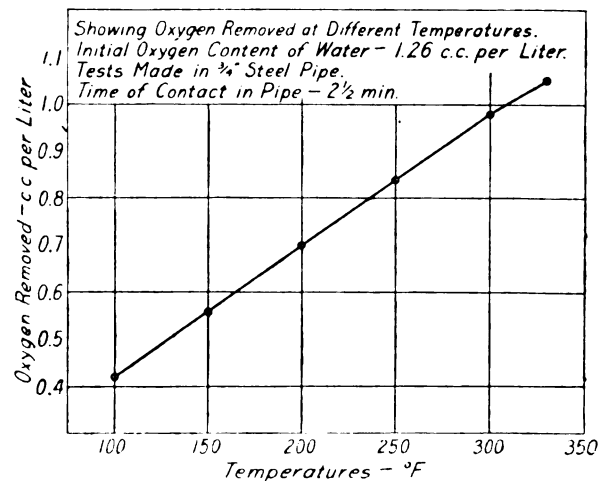


Fig. 6.

ferric hydrate which always forms a large proportion of these scales. The study which the writer has made of pipe corrosion with various domestic waters has shown that there is a marked difference in the life of pipe in certain localities—one of the most noticeable contrasts in this respect is between the rate of corrosion of pipe used in the Great Lake cities where a comparatively hard scale-forming water is used, in comparison with the action of domestic water of New York or New England, which is relatively purer and softer. Generally speaking, hot-water pipes under the former conditions last two or three times as long as in the later, other factors being the same.

It is quite possible that some practical means will be developed to give domestic water this scale-forming property without making it objectionable in other respects. Some research work on this problem has been under way for a year or so in our laboratory, which indicates that while such protection is incomplete compared with deactivation of water, that it is possible to form a coating on the inside of pipes under certain conditions, which will cut down corrosion sufficiently to prevent all but a slight discoloration of the water.

Dissolved Oxygen in Water.

The controlling influence of free oxygen on corrosion in water is clearly indicated by the electrolytic theory and has been repeatedly demonstrated by experiments and confirmed by practical experience (Fig. 3). The solubility of oxygen in pure water follows the Law of Henry, which states that the solubility of a gas at a given temperature is proportional to the pressure of the gas above the solution. Expressed as a vapor pressure law, this means that the partial pressure of a volatile solute from a solution is proportional to its molecular fraction or to its concentration.

The solubility of oxygen in salt and fresh water at atmospheric pressure varies with the temperature as indicated in the chart (Fig. 1).

The chart shown in Fig. 2 was prepared by Mr. T. M. Knowland for a report for the National Tube Company from work in the Massachusetts Institute of Technology Research Laboratory and will be found useful for calculating the amount of oxygen dissolved in water from air at any temperature or pressure.

The solubility of iron in water is usually so low that in the absence of oxygen, corrosion is negligible except, as we have pointed out before, where the concentration of H ions is considerable and is maintained by some means, in which case such corrosion cannot be ignored. However, this condition is rarely found in domestic water and but occasionally in water used for power purposes. In these cases the acid or acid-forming compound, which is usually magnesium chloride, may be neutralized by the addition of lime.

Fig. 3 shows in diagrammatic form results of a series of weighted tests of corrosion in water, made under constant conditions but

with varying oxygen contents. The water was passed continuously through a series of steel cylinders (Fig. 4), in which were placed varying amounts of perforated steel sheets so that the oxygen content of the water was reduced by stages.

The problem of protection of metal pipes or tanks carrying water is therefore one of removing the free oxygen from the water before it enters the system and preventing further supply of oxygen. To secure practical immunity from attack, it is not necessary to remove all the free oxygen; the amount which may be tolerated depends on the temperature and amount of water passing through the system. For example, a hot-water service system for a building where water is used at 135 deg. will show no serious corrosion with an oxygen content of 1.0 c.c. per litre; at 170 deg. F., to get as good results, the oxygen contents should not be over one-half of this, or 0.5 c.c. per litre; and in the case of a boiler economizer operating at 300 deg. F., the residual oxygen would probably have to be reduced to 0.2 c.c. per litre to reduce corrosion to a negligible amount. There are other factors, of course, which make this estimate only approximate, but as it is a more difficult and costly matter to remove the last one-half c.c. of oxygen per litre from water, the degree of removal required is one of the main considerations in determining the selection of the most suitable and economical apparatus for any particular case.

Oxygen removal apparatus has been developed to a high degree of efficiency in this country during the past six years as a result of various designs which have been worked out in service.

These may be divided into three classes, according to the principles employed:

1. Apparatus for oxygen removal by chemical means.
2. For oxygen removal by mechanical or physical means.
3. Combinations of the above in the same plant.

Oxygen Removal by Chemical Means

(Deactivation of Water) In the United States.

We have frequently noticed that in service more corrosion is found near the inlet to a pipe system than farther away; that in boilers there is more corrosion near the feed-water entrance; and that in hot-water heating systems where only a relatively small amount of water is added each season, no serious damage occurs. Such experience and the viewpoint of corrosion given by the electrolytic theory, led the author to experiment in 1906 with the removal of free oxygen from water by means of contact with a large surface of scrap iron for which apparatus was built in the Research Laboratory of the National Tube Company. Favorable results were obtained, but continuous operation of such a long period of time required considerable experimental work on a working scale, and it was not until 1915 that

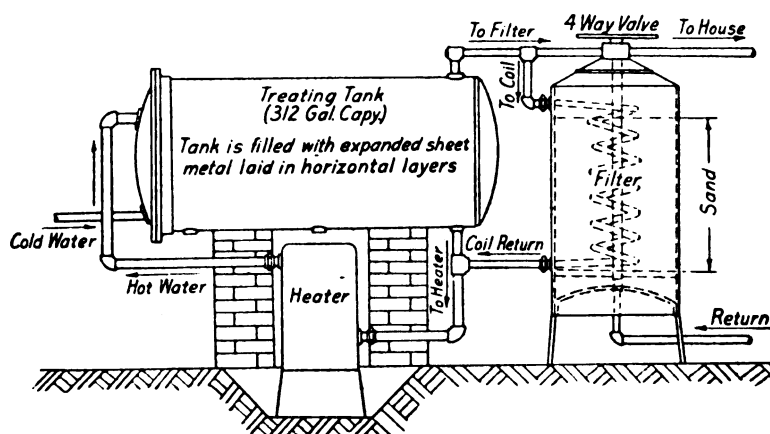


Fig. 7.

Water heater and deactivator for apartments in Boston.

a satisfactory plant constructed on this principle was put into working operation in a building in Pittsburgh.*

For lack of a distinctive name, the word "deactivator" was adopted to describe such an apparatus, for water after having most of its dissolved oxygen removed in this way, has been found to be inactive toward iron. The deactivating tank is preferably filled with a special type of expanded steel lathing (about 26-gage), so formed that the individual sheets will not lay so close as to cause excessive resistance to flow. Miscellaneous steel turnings usually rust together in a tight mass in time so as to seriously interfere with flow. Figs. 5 and 6 show the influence of varying temperature on deactivation. The density of the steel, as expressed in square feet of surface per cubic foot of volume, is another important factor affecting the rate of oxygen removal by this method.†

A later form of deactivator installed in an apartment in Boston in 1917 is shown in Fig. 7. A filter was provided in order to secure clear water free from iron hydroxide; the iron found in solution in the filtered deactivated water is usually less than 0.2 p.p.m. Experiments conducted by Dr. W. H. Walker and his associates at the Massachusetts Institute of Technology, Industrial Research Department, on coagulation of iron in deactivated water, developed the fact that by rendering the water slightly alkaline to phenolphthalein, the colloidal iron could be readily coagulated, and that passing water through a slightly soluble form of granular magnesium oxide was a very convenient means for accomplishing this result. This gave a simple and automatic control of coagulation, which materially increased the efficiency of the filter. This experience suggested to the author the possibility of flocculating the hydroxides of iron to such an extent that they would be retained on the expanded sheet steel of the deactivating tank. Experimental work on the influence of temperature, rate of flow, and alkalinity on the production of clear deactivated water, showed that with a certain relation between these factors good results could be accomplished. The most favorable conditions under which clear deactivated water can be obtained in service without the use of a filter have been developed by tests on plants in operation, includ-

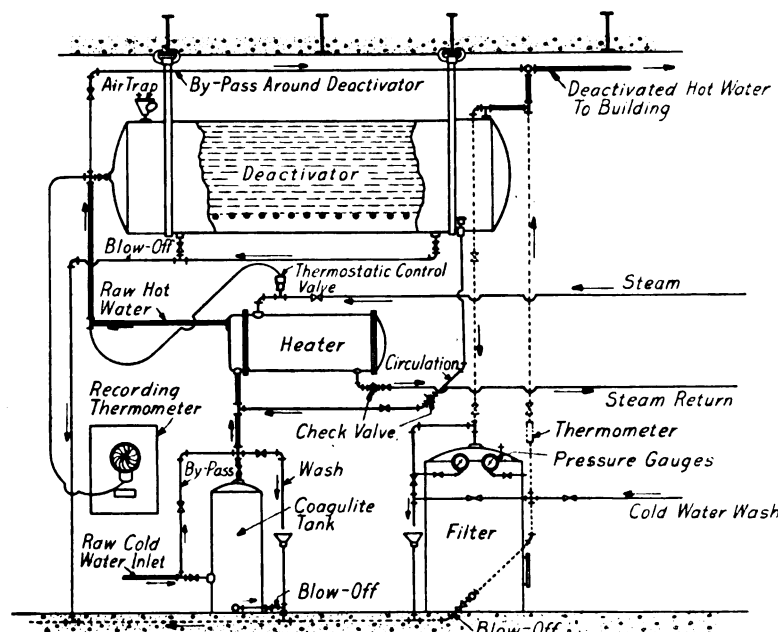


Fig. 8.

Hot water deactivator. Heavy lines indicate course of water when not using filter. Light lines indicate by-passes and other necessary connections.

ing the one shown in Fig. 7, which now operates without the filter. Fig. 8 shows the latest form of apparatus for this service in which the filter may be omitted or by-passed as desired.‡ However, the rate of consumption of hot water in some buildings is so variable that a filter may be necessary in some cases in order to secure perfectly clear water at times.

European Practice.

Another form of apparatus for removing dissolved oxygen by use of steel scrap has recently been brought out by Kestner and Paris in Europe and is described in a paper by G. Paris*. The novel feature claimed for this is intermittent and reversible flow, based on the assumption that ferric hydroxide is reduced to the ferrous form when allowed to stand in contact with iron and water for some time. Under these conditions the iron hydrates lose their reddish color to some degree, but we have not found them to be more active in this form even after the deactivator has been allowed to stand at rest for 30 hours. Moreover, most of the plants constructed in this country have operated with periods of rest of at least several hours each day with no perceptible regenerating influence, so that while we have found a slow falling off in activity, the deactivator has been found to function for as long as four years without renewal with satisfactory results. The author is inclined to believe that the change in color of ferric hydroxide from red to black on standing is due to dehydration rather than to reduction to the ferrous form. However, in this connection, attention should be called to the fact that freshly precipitated ferrous hydrate removes dissolved oxygen from water with great rapidity compared with iron; for instance, Mr. R. G. Knowland, in our research laboratory in 1918, found that freshly precipitated ferrous hydrate combines with all the oxygen in water at 160 deg. F. in a few seconds, whereas steel sheets packed with surface density of 70 square feet per cubic foot of space required at least 40 minutes' contact to remove 80 per cent of the oxygen at this temperature. The advantage of the steel sheet method, however, is that it is entirely automatic and will operate for two years or more in a properly proportioned plant without more than casual attention by unskilled help.

A type of deactivator very similar to some of those which are in operation in this country has been brought out recently by the Metropolitan-Vickers Electric Company of England and another by Hulsmeyer in Germany for power plant purposes, but so far as the records go, none of these have been put to more than very limited use as yet.

(To be continued next month.)

*Described by the Author as "A Method for Practical Elimination of Corrosion in Hot Water Supply Pipe," Proc. A. S. H. and V. Engineers, vol. 23, 125, 1917.

†U. S. Patents No. 900,323, No. 1,204,602, No. 1,274,099 (F. N. Speller) refer to the application of this principle to the removal of free oxygen from water.

‡"Les Corrosions Du Fer et leur Suppression par le Dégazage de L'eau," Chimie et Industrie, vol. 6, No. 1, July, 1921.

The Joy of Being a Chemist

By D. M. STRICKLAND

Research Engineer, American Rolling Mills Company

CHEMISTS have discovered not only some eighty-odd formulae for home brew production, but also that all matter is made up of varying proportionate amounts of some eighty-odd elements. They further declare that each element, when divided into its smallest existible size, produces atoms. Thus, we have atoms of lead, mercury atoms, oxygen atoms, iron atoms and so on through the list. In fact, it is correct to say that all matter is made up of atoms; atom being being the family name, so to speak, while the eighty-odd individual names characterize the family members.

"Atoms are little, firm, hard balls" is the statement I found one time when grading chemistry students' quiz papers. This definition amused me. I put a big blue ring around it and wrote an ironical marginal notation. Yet, the student was not far from the truth. There is no doubt but that atoms are little. Just call to mind the smallest thing you can imagine, divide it into a few million parts and perhaps you will have estimated the size of a member of the atom family.

If you interpret "firm hard" to mean tenacity on the part of the atom to hold its individual physical and chemical characteristics, the inability of human manipulative skill to divide it or change it into other elements — then, the above definition is plausible. A scientist would say, "Atoms (Greek meaning indivisibles) are, since matter is incapable of indefinite subdivision, the ultimate particles resulting from ideal separation." I'll leave it to your judgment which definition suits your taste.

An inestimable number of atoms must exist side by side before we have a visible quantity of an element. Take a chunk of iron the size of your fist and, if you are spending a few years idle time waiting for the next Democratic administration, hold it before your eye and try counting the number of atoms you imagine the piece contains. Or, if you suffer from insomnia, take it to bed with you and count: atom one—atom two—atom—ato—at—at—etc.—much more up-to-date and scientific than counting sheep as they hurdle the fence.

When two or more different atoms join partnership and enter a state of chemical union, a molecule is formed. It only takes a few billion similar molecules to form an appreciable quantity of a compound. For example, sodium atoms unite with chlorine atoms to produce sodium-chloride molecules. Now, sodium chloride is nothing more or less than common table salt; that white crystalline substance which pours out of the June bride's silver-plated saltcellar and is blasted out of such antideluvian queensware shakers as are found in restaurants, cafeterias, and boarding houses.

Iron in its original elementary state belonged to the atom family—that inner circle—the staid old group of 80.

Unfortunately, however, for the human race in general (but to the decided financial betterment of the iron and steel business in particular) it turned out to be

one of the black sheep of the family. Refusing to live up to such high standards as did its more noble brothers, gold and silver, it united with various other elements to form compounds. So iron atoms joined oxygen atoms forming iron-oxide molecules—or, generally speaking, iron ore.

This good old ore lay undisturbed while men of the paleolithic age fought with stones, hunted with flints, wooed with clubs, shuddered at lightning, and gave up the ghost. No human hand disturbed the ore during the stirring times when the armies of ancient history spanked each other with bronze spears, copper shields and brass knucks. So man advanced through the stone age and bronze age; acquired more knowledge and lawyers — more politics and prohibition — more science and patent medicines—and, finally, more need of this article which shows how important a part the chemists have taken in winning iron back to the original atomic family after centuries of molecular wanderings and backslidings.

The purification of iron ore is no simple matter. To separate iron from the elements with which it has existed in chemical combination for ages and ages is not an easy task. In fact, those who are not familiar with steps necessary for the manufacture of commercially pure iron will be surprised at the number of purification rounds which must be fought before the clinging impurities are knocked down and out.

Stamp vending machines, jazz records, Bolshevism, Jimmy Cox's presidential race and the economical production of commercially pure iron are all developments of the twentieth century. To produce iron which conforms to purity specifications, it is imperative that the contaminating impurities be present in traces only, say to an aggregate amount of less than one-fifth of one per cent. Now, one-fifth of one per cent means that Casey must come to bat some five hundred times for a total of one hit. An out-fielder with an average like that wouldn't be permitted to play ante-over at an old maids' home.

Iron ore contains approximately 55 per cent iron and 45 per cent impurities. The best grade ore is found in the Lake Superior regions. First, it is mined, generally by stripping off the upper soil stratas and digging out the exposed mineral. Very simple, just like taking the lid off of a nut and picking out the goodies. The ore is transported to manufacturing centers by rail and ship. The ship loading and unloading facilities are monumental examples of human achievement and inventive ingenuity. Thousands and thousands of tons of ore are handled each year with as much ease as a drunken sailor handles money.

The first purification process is the reduction of ore in blast furnaces. The ore mixed with weighed amounts of coke and limestone skips up the hoist and jumps into the top of the blast furnace stack, the skipping and jumping being accomplished by a gener-

ous application of pulleys, ropes, bucket cars, and sundry other mechanical devices.

Superheated air is blown into the stack by means of tuyere pipes leading into the furnace at a height of about 10 feet from the ground. Vast volumes of this superheated air are blown into the furnace every minute, a regular Senatorial blast in fact. Within the stack, the coke burns, the oxygen atoms are separated from the iron atoms, the charge melts, the drops of iron trickle down to the hearth at the bottom while the lighter liquid impurities float on top of the molten iron. From time to time the metal is tapped out of the furnace and run into moulds where it solidifies. This product of the blast furnace is commercially known as pig iron.

The slag or liquid impurities when run out of the furnace become the source of livelihood for waste product engineers. Studying the what-to-do-with-blast-furnace-slag problem has brought the \$3,000 a year to many an efficiency expert and the sum total of their conclusions indicate that slag can be economically used for paving materials, mineral wool, cements, and ballast for Henry's D. T. & I.

Pig iron usually contains from 5 to 8 per cent impurities. It is an intermediate product obtained in the iron and steel manufacturing process and is used for remelting purposes only, having no other value except as a producer of revenue for blast furnace owners. Further purification of pig iron is usually accomplished by either the Bessemer or the open hearth process. Commercially pure iron is made in open-hearth furnaces; the product of the Bessemer process being steel which generally varies in iron content from 98 to 99 per cent. Ordinary irons and steels are also made in open-hearth furnaces, but these products do not require such exacting manufacturing care as is necessary for purity iron production.

The manufacture of pure products is always attended with difficulty. The development of satisfactory purification processes requires careful experimental testing, scientific experience, and a thorough knowledge of the accomplishments of preceding generations of investigators. This is true, not only for iron, but for zinc, copper, lead, and metals in general. It is equally true for soaps, gasolines, paints, oils, cosmetics, foods, beverages, and life's necessities as a whole. Although it increases production costs, yet, American buyers demand that their purchases conform to ridged purity qualifications. Chautauqua circuits demand Bryan as it is universally known that William Jennings drinks only the purest grape juices obtainable. Even Michigan demands the best politicians money can buy.

The blast furnace pig iron when mixed with scrap iron and limestone is charged into the open-hearth furnace. In the good old days when saloons had a front as well as a back entrance, this charging was done by hand and a gruelling, back-breaking job it was, too, but now the materials are weighed up in pans on buggies and run up in front of the furnace doors where a charging machine grabs the pans and dumps the contents on the furnace hearth. Artificial or natural gas burns across the furnace above the charge and produces a temperature several degrees warmer than a front seat in Billy Sunday's tabernacle.

After several hours the iron and purifying flux melt down and are ready to tap. Right now, however, is where science steps in. When open-hearth melts are

tapped at this point, the resulting product is not pure enough so a departure from the usual manufacturing procedures is necessitated. The chemists, those wizards who can tell you how much cotton is present in a \$9.98 all wool suit, now come forward and contribute their efforts and knowledge toward reducing the remaining traces of impurities to a minimum—that one-fifth of one per cent mentioned above.

I used to juggle test tubes in an open-hearth laboratory. I soon learned what it meant to hold a hundred tons of molten iron in the furnace while the final purification was accomplished. I recall one sizzling hot July afternoon about three weeks after I started to work. While I was creating a whirlwind of useless laboratory activity in an effort to impress my superiors that a college man might possibly amount to something after all, an open-hearth furnace helper brought me a preliminary test. He was a typical furnace man; a big, strong, good-natured, hard working foreigner. His undershirt, trousers, and shoes were soaked with perspiration. His blue lensed furnace glasses were pushed back on his forehead and a bandage on his arm located the most recent hot metal burn. After handing me the test he drank a quart of water, sat down, and wiped his face with a handkerchief in which overall blue was the prevailing color.

I knew that a preliminary test was a spoonful of metal dipped out of the furnace. I also knew that the men were working with the molten iron in the furnace, awaiting the results of my analysis, and hoping that the impurities would be low enough that no more delay would be necessary. I tested the sample as rapidly as possible. When the results were obtained I turned to the foreigner and said:

"John, you will have to bring another test."

"Whazzamat? Too mooch sulphur?"

"No, sulphur is low enough—copper and phosphorous are all right—too much manganese."

"Too mooch magnas? Hell!"

Never had I heard that simple expletive delivered with more feeling. The results of my analysis meant that he and his companions had to work in front of the furnace doors throwing additional purifying agents into the boiling iron and continue to do so until subsequent tests and analyses showed that the metal conformed to specifications. No wonder he was moved to violent expression.

Long haired poets sit along the sea shore, musing in iambic pentameter measurement and wondering what the wild waves are saying. Stock brokers and millionaire cooks, motorists and flivverettes, artistic temperamentalists and sensible citizens wander all over the Garden of the Gods, Yellowstone Park, and the globe in general, audibly expressing their conceptions of the beauties of nature and wondering what the next head waiter will think when he gets his tip. The bowery pawnbroker and his family enjoy a Coney Island boat trip, callisthentially tickled that little 10-year-old Isaac got through the gate for nothing and wondering whether they put the cat out and locked the back door. And so it goes. Everybody, everywhere, hunts for novel amusements, new scenery, and nature's wonders.

Let me give you an idea. The next time you feel the need of a beautiful and wonderful sight, something out of the usual humdrum existence—take a trip to the nearest open-hearth furnace plant and watch the tapping of a heat. You will be well repaid for your trouble.

Witness a hundred tons of white-hot molten iron running out of the furnace down the trough and pouring into the brick-lined ladle; long tongues of flame leaping higher and higher; scintillating sparks shooting up, out and every which way. Watch the ladle fill to the brim and see the liquid slag swirl and dart and boil on the top of the metal, finally overflowing with a second display of sparks into the slag pot. Realize the consequences of a false step on the part of the men who open the tap-hole and hover about the flowing metal; metal which would snuff out their lives in the twinkling of an eye. Listen to the roar of the falling iron, the grinding of gears and wheels, the hoarse shouts of foremen. Wonder at the precision-like efficiency of the controlling machinery. Watch the gigantic crane hook onto the ladle and lift it as if a feather, carrying the tons of molten metal to the mold train, losing along the way such metal as overflows the top and falls to the ground in a veritable shower of brilliants and diamonds. Now, double the beauty of the whole spectacle by choosing a midnight hour and let the inky darkness of night give a contrasting background against which the sparks and flames and fires will shine out in all their radiant splendor.

After you have witnessed the tapping of a heat you are qualified to talk scenery with anybody. Call to mind that old bore who lives around the corner. You remember he went to Niagara Falls on his wed-

ding trip 40 years ago. He never forgot it or permits anybody else to forget it. Hunt him up and say:

"Neighbor, did you ever see an open-hearth furnace tap?"

"Naw. But I DO remember what I saw about 40 years ago, etc.—"

Now, crush him. You have the ammunition.

The bubbling iron is held within controllable bounds by humanly devised mechanisms. Before tapping, it is held in check while the chemist demands of science, "Is it pure enough?" Then it's great to be a chemist. You are the whole show at this stage of the manufacturing process. You're responsible. Before pure iron can be produced, you are a vital factor—you must contribute something—you must use your ability and skill. The superintendent as well as the furnace helper stands around and waits for you to say, "Yes" or, "No."

When the analyses are completed and science is satisfied—while you watch the metal pour out of the furnace—you have that enviable feeling which comes with a realization that work is well done. You have a feeling of accomplishment, a desire to tack a sign on your back which says, "I've done something. Look at me," and then parade around in front of kings, princes, and presidents; before relatives, friends, and strangers—anybody—anywhere.

Reducing the Cost of Handling Coal

Statistics Showing a Saving of Cost of Handling Bulk Material
by the Use of Better Belt Conveyor Idlers.

By J. M. KELLY*

IN the handling of coal, coke, ore, limestone and other bulk materials about a plant, belt conveyors are fast coming into more extended use. It is important to secure uninterrupted conveyor operation at the lowest cost per ton, and careful consideration of the type of troughing and return idler bearings is therefore well worth while.

In computing the power required to drive a belt conveyor delivering a certain tonnage at a given speed, various formulae are used, but the most general is:

$$\text{Power} = \frac{\text{Constant} \times \text{Capacity} \times \text{Length}}{990} + \frac{\text{Capacity} \times \text{Lift}}{990}$$

The constant depends on the belt width and the weight per cu. ft. of material handled.

The capacity is expressed in tons of material per hour.

The length is the distance between centers of head and tail pulleys expressed in feet.

The lift is the vertical distance through which the material is lifted and is expressed in feet.

*Engineer with Hyatt Roller Bearing Company, Pittsburgh, Pa.

For this formula various authorities give the value of the constant as .138 for a 48-in. belt conveyor handling coal which weighs 50 lb. per cu. ft. when plain bearings are used.

A recent test was conducted on a belt conveyor, the troughing and return idlers of which were equipped with anti-friction bearings of the flexible roller type.

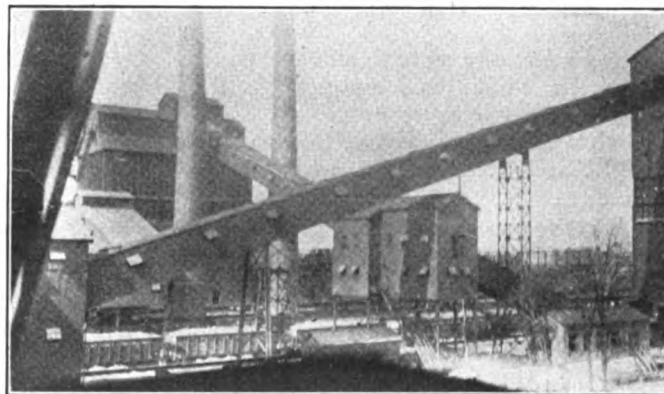


Fig. 1.—View of conveyor at the new by-products coke oven plant of the Donner Union Coke Corporation at Buffalo, N. Y. This conveyor is equipped with Hyatt Roller Bearings.

Of course the power required to elevate the coal through the vertical distance will remain the same regardless of the type of troughing and return idlers, but the friction horse power, which is for the most part the power required for the belt to overcome friction in the idlers, is materially reduced by the installation of efficient bearings.

The specifications and measured factors on the conveyor tested are as follows:

Belt Width	48 in.
Length	404.5 ft.
Lift	119.13 ft.
Measured Speed	505.6 ft. min.
Measured Capacity	1,020.52 tons hr.

Substituting these items into the above formula the power required to drive the conveyor when equipped with plain bearing idlers would be 180.34 hp. Of this



Fig. 2.—This long roller bearing equipped conveyor is reducing power and maintenance items of an important steel company in the Ohio Valley.

power, 122.8 hp. is required to lift the coal through the vertical distance of 199.13 ft. while 57.74 hp. would be the friction consumed in the idlers. The constant of .138 which was checked on other 48-in. conveyors equipped with plain bearings would be used in this calculation.

However, the actual power required to drive this conveyor which was equipped with the anti-friction flexible roller bearings was only 148.4 hp., 122.8 hp. of which was used to elevate the coal through the vertical height and 25.6 hp. to overcome the friction in the idlers.

This represents a saving of 31.94 hp. in favor of the anti-friction bearing equipped idlers.

The saving made possible by the use of roller bearing idlers on this conveyor is 55.5 per cent of the power required to overcome friction.

Hence the constant to be used in the calculation of power requirements of a flexible roller bearing equipped conveyor 48 in. wide would be .0614 instead of the .138 used for the plain bearing conveyor.

Not only does this reduction in power mean a

power saving, but it also means a reduction in the number of belt plies which need be used in order to operate economically and with assurance of long life for the belt. The reduction in power permits a reduction in total tension, because:

$$\text{Tension} = \frac{\text{Power} \times 33,000}{\text{Speed}}$$

As the maximum tension is reduced on account of the reduction in power, the unit stress per inch of width per ply remaining the same, a reduction in the number of plies of belt is effected.

This reduction in the number of plies of belt effects a saving in the first cost of the belt as well as in the cost of replacement when the belt is no longer considered useful for conveyor service. The life of the belt of course varies and is estimated between four and five years.

In addition to these economies in conveyor operation made possible by the use of flexible roller bearings in the troughing and return idlers, definite savings can be made in the cost of lubrication, material and labor to apply it. Idlers equipped with bearings of the flexible roller type require lubrication only twice each year, because a reservoir for grease is established within the bearing, and all surfaces are continually lubricated. Belts do not wear out prematurely, due to improperly lubricated idler pulleys, and the continuous service, which is assured from easy turning idlers, is worthy of special attention.

These economies about a steel plant are nothing new, since in many plants similar economies in maintenance, upkeep, power consumption and lubrication costs have been effected by roller bearings on mill tables and cars for several years past.

Tests on other plain bearing and flexible roller bearing equipped conveyors of various belt widths have been conducted and the power constants to be used in the general horse power formula have been determined.

In the design and construction of new belt conveying equipment these items of power saving, maintenance and increased life from the equipment are being given more attention. The available data from tests of belt conveyors of various widths can be advantageously used in designing new conveyors so that uninterrupted conveyor operation at the lowest cost per ton can be assured from the start.

PURDUE MAN AIDS 57 FOUNDRIES IN STATE

During July and August R. E. Wendt, of the Engineering Staff of Purdue University, visited 57 foundries of Indiana and interviewed 100 foundrymen in an effort to help them solve their problems. Mr. Wendt is an expert of extensive practical experience, and teaches foundry work in the Purdue University Engineering Schools.

The plants visited were very appreciative of the engineering extension work offered by Purdue and were delighted that this work has now been extended to the foundries of the state. Many of the foundrymen were in favor of holding a conference or meeting at Purdue University next spring.

A number of the foundrymen expressed their willingness to take Purdue students into their plants during the summer vacations.

Modern Steam Generating Plant

The Heppenstall Boiler Plant Is Modern and Up-to-Date in Every Detail—It Has Been Designed to Meet Special Requirements Due to the Location of the Plant and to Unusual Service Demands.

BY R. F. KEIFER*

A WORD picture of the works of the Heppenstall Forge & Knife Company would not be complete without a description of our steam generating or boiler plant and, assuming this to be an interesting subject to engineers and operators, we will endeavor to describe the same in detail.

For several years the proposition of utilizing the waste heat from the forge furnaces for the generation of steam power was given careful consideration, and it was only after due deliberation and a thorough trial that this scheme was discarded and the isolated and scattered units, making up our steam producing equipment, were superseded and replaced by the present splendid and centralized plant.

As is the case in all industrial plants when located in the heart of a thickly populated district, the question of available space is a serious one and the plant must be designed to not only give maximum efficiency, but must do so in the minimum amount of space, bearing in mind at all times the requirements of the particular plant in question; this of course covering the question of receiving and handling coal and the disposal of ash.

Description of the Building.

In general, the building is 47 ft. wide and 85 ft. 4 in. long—inside measurements—of steel framework and brick walls. The building is divided into two bays crosswise and four bays lengthwise and is provided with a lean-to at one end approximately 19 ft. square. The building is also provided with a basement, the floor level of which is 15 ft. below the boiler room and 6 ft. above general yard level.

*Chief Engineer, Heppenstall Forge & Knife Company.

The two bays, into which a cross section of this building is divided, are designed so that one bay contains the coal bunkers and the other bay will accommodate the boilers. All building foundations extend 3 ft. above basement floor level, resulting in a very pleasing effect of a 3-ft. concrete belt course below the brick walls.

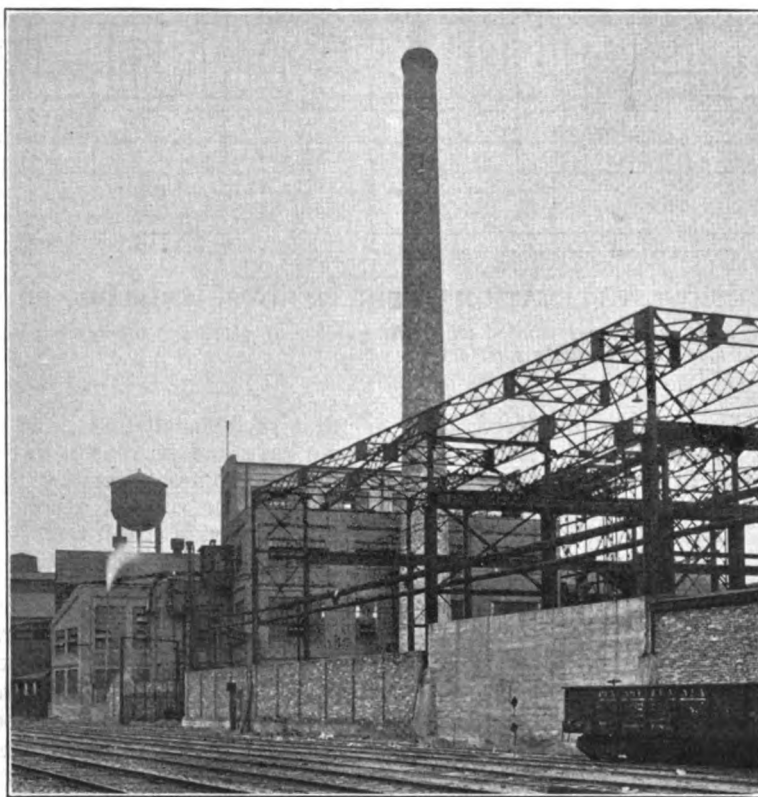
The structural steel framework consists of three rows of two columns—two rows extending to a height of 53 ft. above the basement floor level and were designed to support the coal bunker and mono-rail and roof above the coal bunker. The rear row of columns extend to a height of 49 ft. above the basement floor level and are designed to support the roof.

A monitor of structural steel has been provided approximately 17 ft. 6 in. from top strut of coal bunker to under side of room beam, and designed suitable to support a mono-rail track with telfer and a loaded $1\frac{5}{8}$ cu. yd. bucket. This monitor is approximately 19 ft. wide and is equipped with a structural steel walkway on one side, across one end and for one bay 23 ft. 8 in. long on the other side to give

access to the mono-rail crane for repairs and inspection.

The center row of columns is in line with the front of the boilers, and were designed of sufficient strength to carry a heavy girder suitable for supporting the boilers.

The floor is reinforced concrete, designed to carry a superimposed load of 200 lbs. per sq. ft., and all openings through the floor were located previous to pouring the concrete and suitable thimbles "cast in place." This feature assures a finished appearance and does away with the possibility of the concrete spalling off the corners from time to time. Stairways are suitably protected by curb angles and hand rails.



EXTERIOR VIEW OF MODERN STEAM GENERATING PLANT

This illustration gives a good idea of the location with respect to the railroad and of the relative position of the boiler house, chimney, coal handling and crushing equipment.

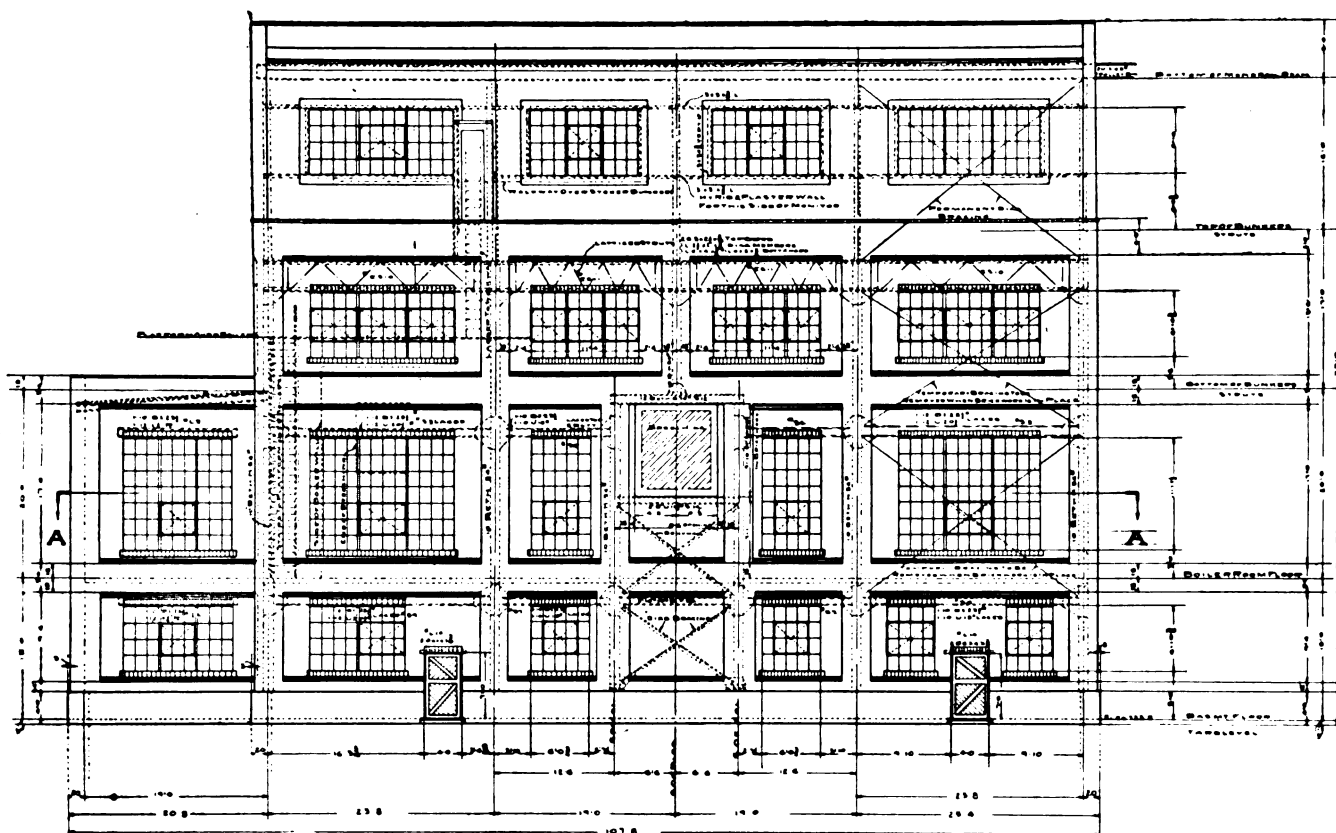


FIG. 1—SOUTHWEST ELEVATION OF BOILER HOUSE AND PUMP ROOM ANNEX

This plant is well lighted, as is readily appreciated when the number of doors and windows is noted. The ventilating sash located in the center of the windows has also proved highly satisfactory.

Brick walls $13\frac{1}{2}$ in. thick, properly pilastered, have been provided, enclosing all structural steel. Brick walls are carried above the roof line to form a parapet and a coping of vitrified tile is placed thereon. The window sills are brick laid on edge. The side wall of the monitor above the main roof is stucco applied on metal lath. Ventilated steel window sash have been used throughout and rolling steel doors have been provided to permit ease in handling large equipment. The arrangement of the windows, doors, etc., is clearly shown on Fig. 1 and Fig. 2.

Coal Bunker.

The coal bunker is approximately 19 ft. wide, 17 ft. deep and 85 ft. long and consists of two inclined longitudinal steel girders, secured to the building columns; these girds in turn furnish the support for a series of steel suspension members supporting the suspension bunker, which is lined with concrete and reinforced with wire mesh reinforcement. The bunker is also provided with eight 12-in. square rack and pinion type gates, operated by means of chain and chain wheels from the boiler room floor, and suitable spouts are also provided to carry the coal from the bunker to the stoker hoppers. The capacity of this bunker is about 700 tons of coal and the clearance above the boiler room floor is approximately 20 ft. This is clearly shown in cross section on Fig. 7.

The roof is a "poured in place" slab of gypsum, reinforced with galvanized steel wire and was installed by the H. H. Robertson Company; the gypsum deck was waterproofed with Johns-Manville 3-ply prepared asbestos Phoenix roofing and when installed was one of the

first such installations, and after almost four years' use we have had no reason to regret our decision. It sometimes becomes necessary to extend special piping, etc., through the roof of a boiler house and the construction adopted lends itself readily to such treatment, for this deck can be easily cut with a hand saw and a neat and "finished" appearance is the result.

A structural steel walkway has been provided above the boilers, carried by brackets on the center row of columns; this walkway is reached by a structural steel stairway from the boiler room floor below. From this walkway access to the walkway above the bunker is had by means of a suitably guarded steel ladder. All stair treads and walkways are of "Irving subway grating," Irving Iron Works Company, as a safety measure. This material will permit no accumulation of dirt and has been adopted as a "standard" for use throughout the works.

Coal Handling Equipment.

For the purpose of carrying the railroad coal track over the concrete pit, track girders designed for coopers E-50 loading with 25 per cent allowance for impact were installed.

If we refer to Fig. 3, we note that starting at the far side of the concrete coal pit and extending to the front wall of the boiler house, a structural steel trestle and mono-rail track have been provided to accommodate a Sprague Combination No. 1831-GB-7, 220-volt, d.c. grab bucket mono-rail crane with enclosed cage and Hayward clamshell Class "E" bucket of $1\frac{1}{2}$ cu. yds. capacity.

Maximum hoist is 85 ft. from bottom of I-beam track to bottom of bucket; hoisting speed 150 ft. per minute; traversing speed 350 ft. per minute.

Many different types of equipment were considered for handling coal and ash and finally this system of mono-rail crane and grab bucket was adopted, and three years' operation have proven the wisdom of this decision, there being practically nothing to get out of order, the upkeep is very low and "breakdowns" almost unknown. This equipment is of such capacity as to readily take care of our requirements, a 50-ton car of coal can be stored in the coal bunker in about three hours by one operator, who, also with the same equipment, loads ashes for carload shipments.

Fig. 4 shows the design and typical details of the structural steel trestle, which is 68 ft. from column base to underside of I-beam track, column bases being 6 in. above yard level. Each bent is constructed in general as shown in Fig. 4 of two columns with suitable cross bracing at the top and properly braced longitudinally so that the structure will not be subject to undue vibration under the load of the traveling crane. As shown on the drawing the mono-rail is supported from the cross framing at the top and was designed to carry the loaded bucket and crane with a safety factor of $7\frac{1}{2}$.

Immediately at the side of the track hopper, toward the boiler house, a steel structure has been provided to carry a bin approximately 11x13 ft. together with a coal crushing and screening outfit, the top of the bin being approximately 40 ft. above yard level. For feeding coal

from the hopper to the crusher, a reciprocating steel plate feeder approximately 8 ft. long is used.

Coal Crusher.

The Heyl & Patterson coal crusher has two 24x24 in. Cornish tooth rolls and is of 35 tons run of mine to $1\frac{1}{4}$ in. capacity per hour, being driven by a 25-hp. G. E. motor. All coal crushers have one roll cushioned on springs to permit the roll to move back to pass unbreakable material, but this crusher does not have the adjustable roll gear driven as is most common, but the adjustable roll is driven from a countershaft through belt transmission, the belt being equipped with automatic tension pulley.

Arrangement for adjusting and driving the rolls will permit the space between rolls to be varied and fixed as desired, and at the same time will permit the adjustable roll to automatically move back the full depth of spring compression in case any unbreakable material be accidentally delivered to crusher, mixed with the coal. With $1\frac{1}{4}$ -in. space between rolls the adjustable roll may move back $4\frac{3}{4}$ in. to pass unbreakable material.

Beneath the crusher and supported by suitable framework a screen has been provided for the purpose of separating fine and coarse coal. The fine coal passing through the screen will be diverted by means of a steel chute to a pit, centered under the mono-rail. The coarse material passing over the screen is diverted by a chute at the end of the screen to an adjacent pit under the mono-rail. The crusher is located beside the steel trestle in a

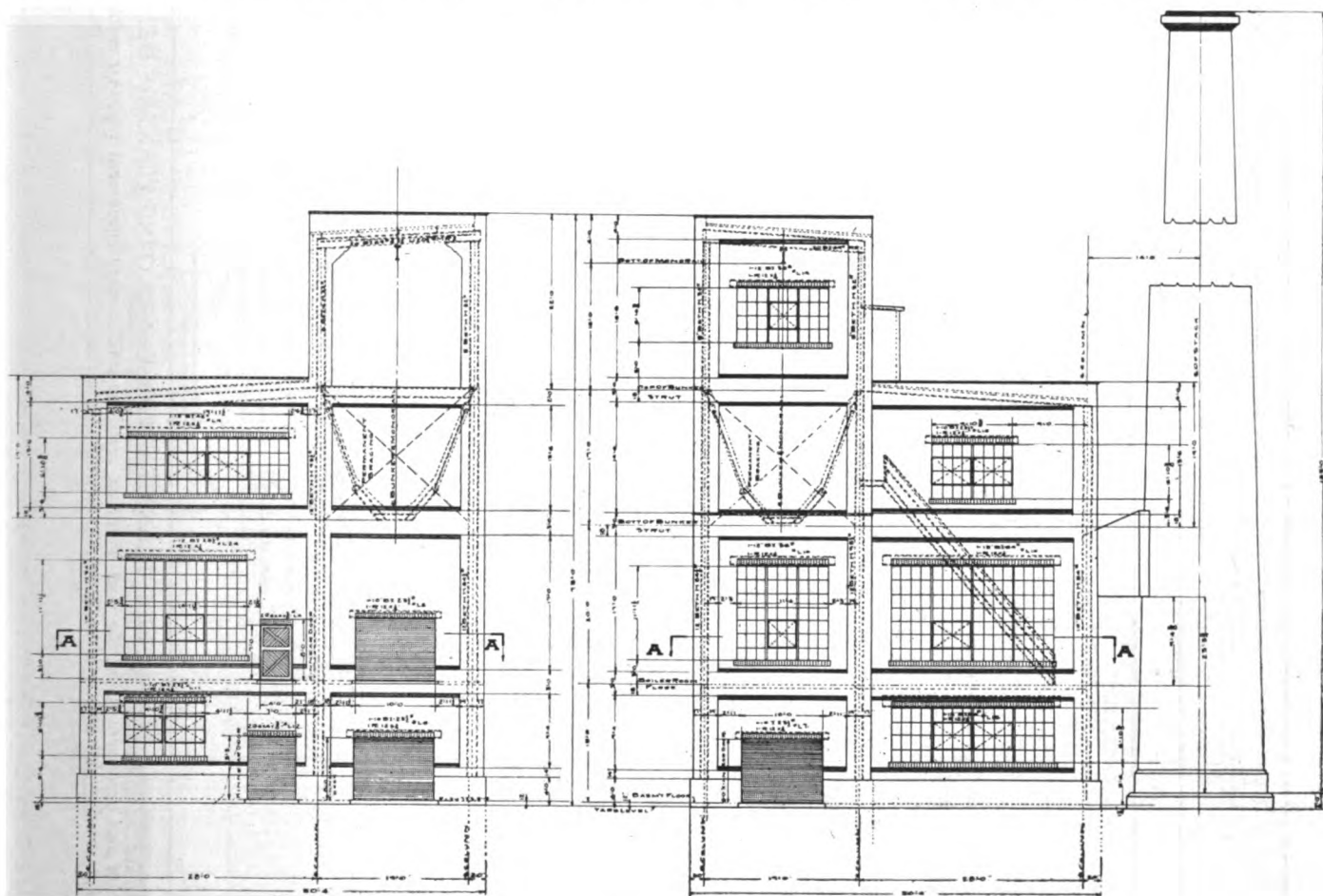


FIG. 2—NORTHWEST AND SOUTHEAST ENDS OF BOILER HOUSE

Arrangement of doors, windows and ventilating sash is shown and the position of the coal bunker is also indicated.

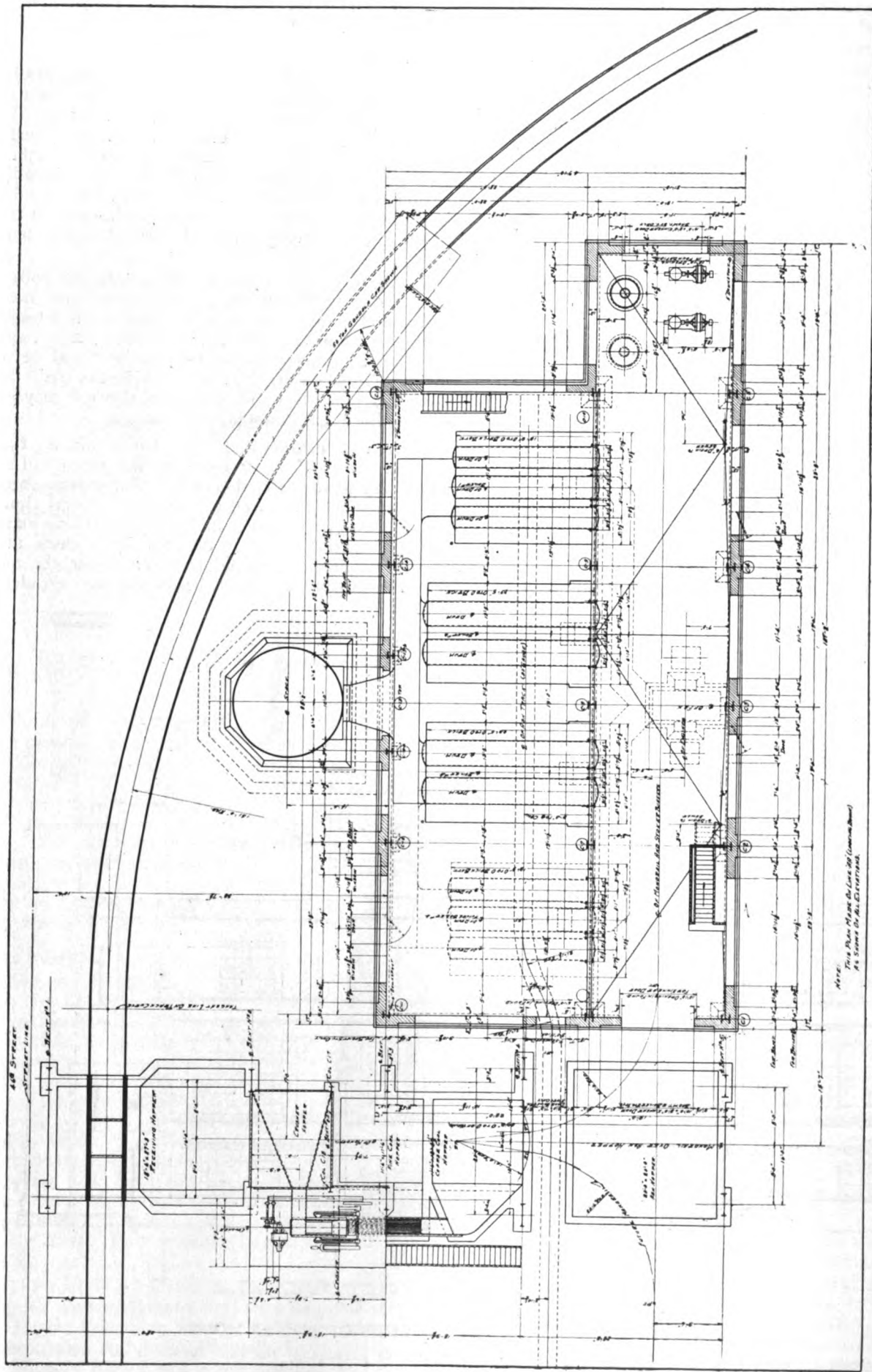


FIG. 3—PLAN OF STEAM GENERATING PLANT OF HEPPENSTALL FORGE & KNIFE COMPANY

Location and arrangement of the coal handling, crushing and storage equipment together with the position of the boilers themselves in the boiler house are indicated. The railroad siding serving this unit is also shown.

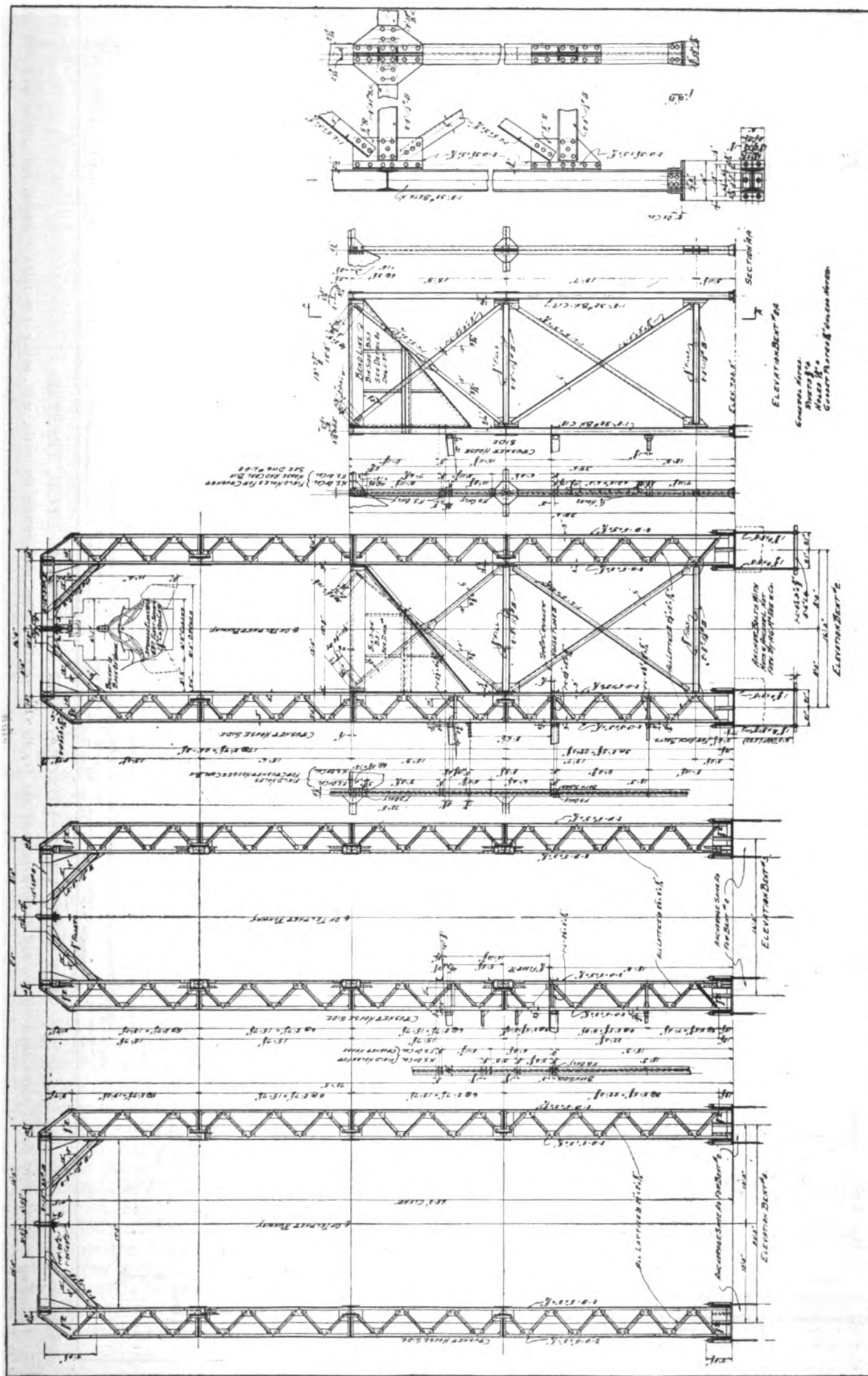


FIG. 4—DESIGN AND TYPICAL DETAILS OF STRUCTURAL STEEL TREESTLE.

Each bent is constructed in general of two columns with suitable cross bracing at the top and properly braced longitudinally so that it will not be subject to undue vibration under the load of the traveling crane. The monorail is supported from the cross framing at the top.

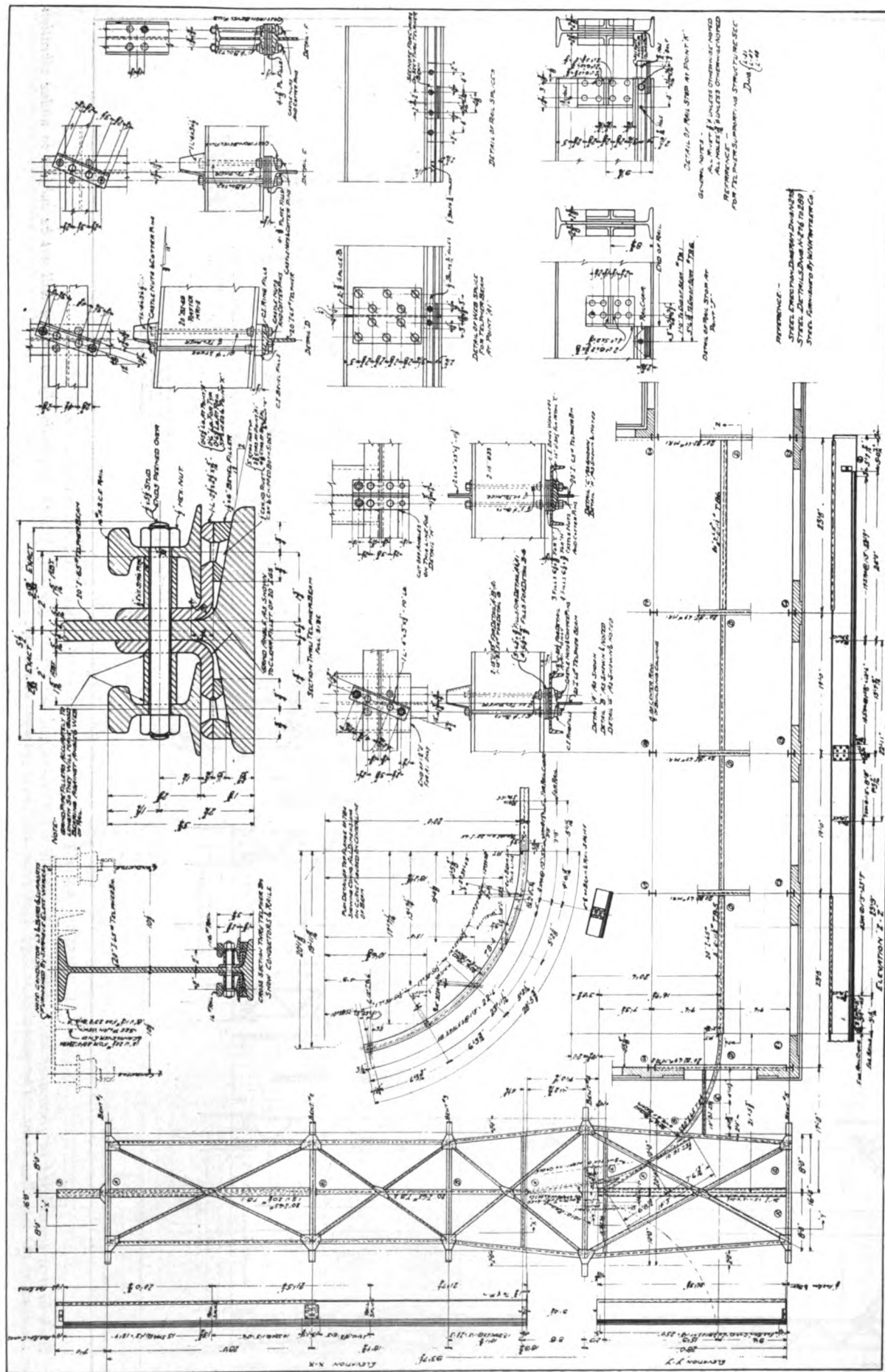


FIG. 5—DETAIL OF MONORAIL FOR STRUCTURAL STEEL TRESTLE

Including a number of detail plans showing the top construction of the trestle, the telfer beam and conductor rails, web splice for telfer beam, rail splice and rail stops at each end.

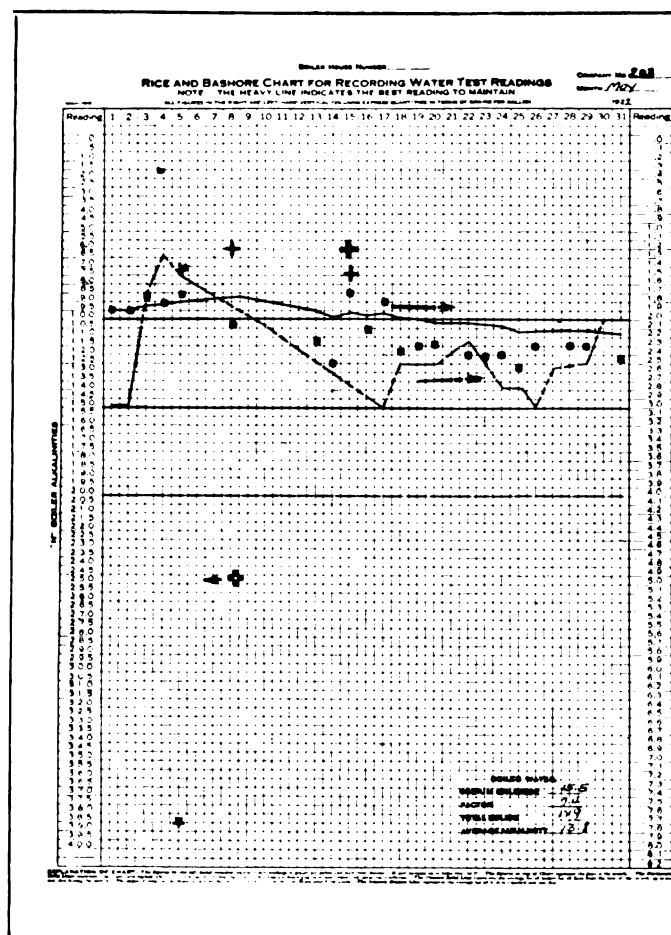


FIG. 6—BOILER FEED WATER TREATMENT CHART
EXPLANATION OF CHART

The figures in the lefthand column represent test readings in grains per gallon.

Small square—Represents the average alkalinity reading for all steaming boilers reported any one day.

Uneven solid line—Represents the average of alkalinity tests for all boilers for all days from the first of the month up to the last day this average is recorded.

Uneven broken line—Represents the average chloride reading of all steaming boilers reported any one day.

Solid cross—Represents the results of our tests for soda concentrations in samples received from the plant.

Broken cross—Represents the results of our tests for chloride concentrations in samples received from the plant.

Star—Represents the day on which a change in treatment was advised by us.

Circle—Represents the day on which the treatment advised was made effective.

Arrow—When placed to the side of a mark points toward the direction on the chart from which the reading is to be taken for all marks of the same kind. Example: One arrow to the right side of a solid cross indicates that the reading for this cross and for all other solid crosses on the chart are to be taken from the right side.

The straight solid line represents the minimum desired alkalinity to be carried.

The straight broken line represents the maximum desired chloride reading to be carried.

All curves shown on the chart as uneven solid lines, broken lines or small squares are plotted on the intersection of the vertical line representing the date on which each test of its kind was reported as being made, and the horizontal line representing the readings.

The solid and broken crosses are placed on the intersection of the horizontal line representing the test readings, and vertical line representing the date the sample was taken, and not the date on which the tests of the samples shipped are made by us.

crusher house 19x11 ft. elevated 20 ft. above yard level.

Coal is received by railroad and is dumped direct from cars to the receiving hopper shown in Fig. 3, from which point it is handled by the Sprague G. B. 7 grab bucket mono-rail crane.

Providing "slack" be received, it is taken direct from receiving hopper to the coal bunker in the boiler house, but if run of mine coal be received, it is lifted by the grab bucket to the 11x13 ft. bin and fed to the crusher by the reciprocating steel plate feeder and from the crusher the coal runs by gravity over the screen and finally comes to rest in either the fine coal or coarse coal hopper, locations of which are shown on Fig. 3, the fine coal being handled from here to the coal bunkers by the grab bucket crane.

Suitable spouts lead from the rack and pinion type gates (controlled from boiler house floor) on the bottom of the coal bunker to the stoker hoppers.

The stokers are Type AA-6 Taylor stokers of 5-retort, 17-tuyere size, built by the American Engineering Company. The three stokers, 15 retorts and the fan are driven by a Troy engine; this fan is of the paddle wheel, three-fourths housed type and is of such size as to operate four stokers at maximum capacity. Two vertical engines, either of which may be direct connected to the fan, are provided; each engine, however, is of sufficient size to operate the fan at maximum capacity and in addition drive four stokers. It is not uncommon to call upon these stokers to burn sufficient coal to develop 225 per cent to 250 per cent of normal boiler rating.

This stoker consists of the following assembled parts:

1. Sloping passages, called retorts, by which coal enters from the hoppers.

2. A series of cast iron tuyere boxes, through which air is forced by a fan, and which are covered by perforated cast iron tuyeres, through which the air enters the fuel bed.

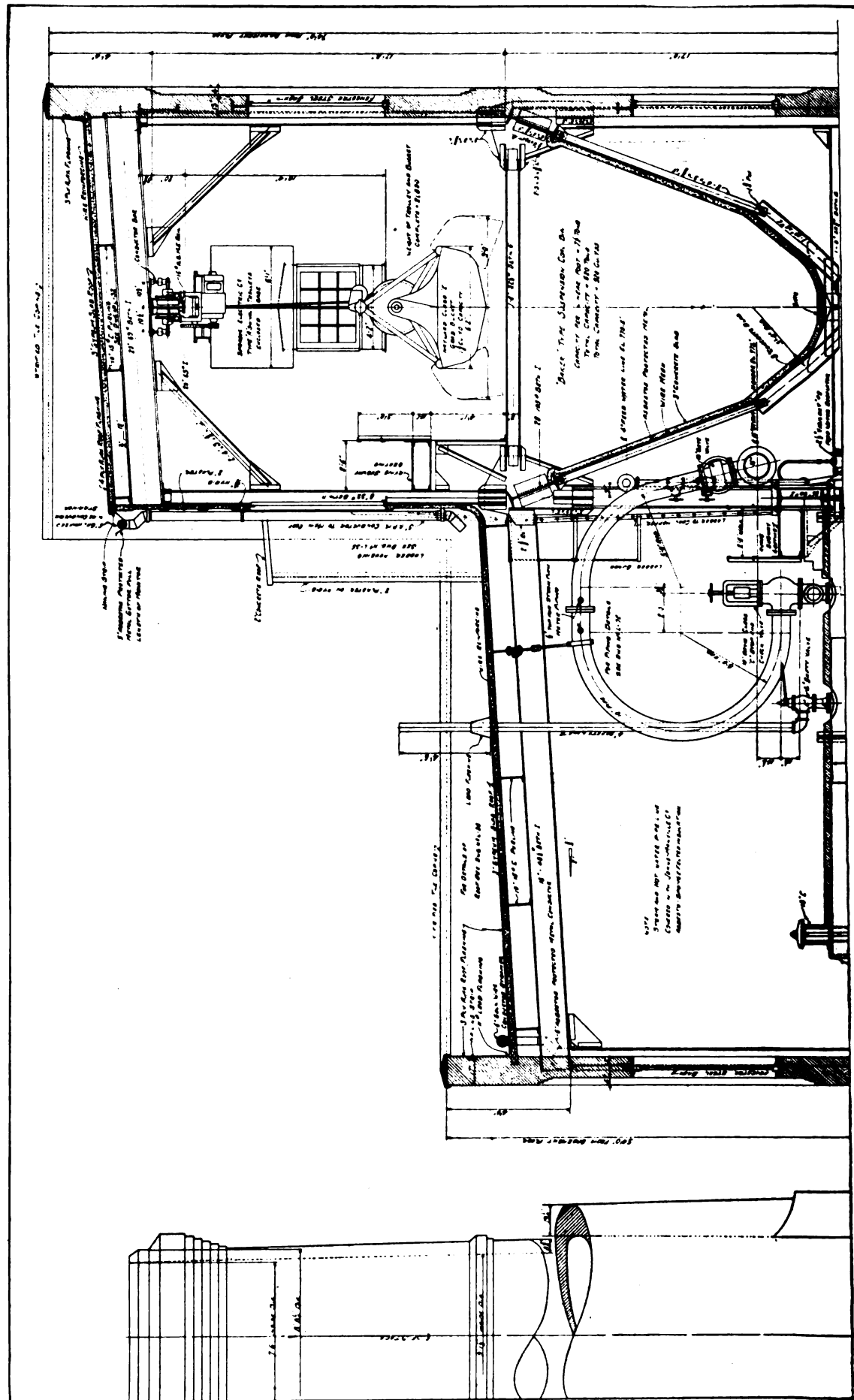
3. Slowly reciprocating rams, driven at variable speed by worm gears from a sprocket shaft. Each retort is served by one feeding ram and a distributing ram. As the coal drops behind them it is pushed upward and backward, working to the surface and eventually past the extension grate to the dump plate, and

4. A dump plate on which hot refuse accumulates and which is dumped every 3 to 6 hours, depending on the rate of working.

The rams are driven by sprockets and worm gearing from a drive shaft below the floor. The distributing ram is operated through a lever from the feeding ram; its stroke is graduated by the lever and may be further adjusted by spacing washers. An extension of this lever imparts a slight movement to the extension grate to prevent clinkers from adhering.

Power is derived from a steam engine; the stokers and fan are run at proportional speeds, according to the load demand.

The first effect of the feeding ram is to push much of the fuel upward. This accounts for the heavy fuel bed—from 2 to 3 ft. thick—which is carried. The green fuel works slowly to the surface, having ample time to distil, and the escaping gases, rising with air from the tuyeres through the incandescent coke above, are thoroughly mixed and burn with an intense, relatively short flame.



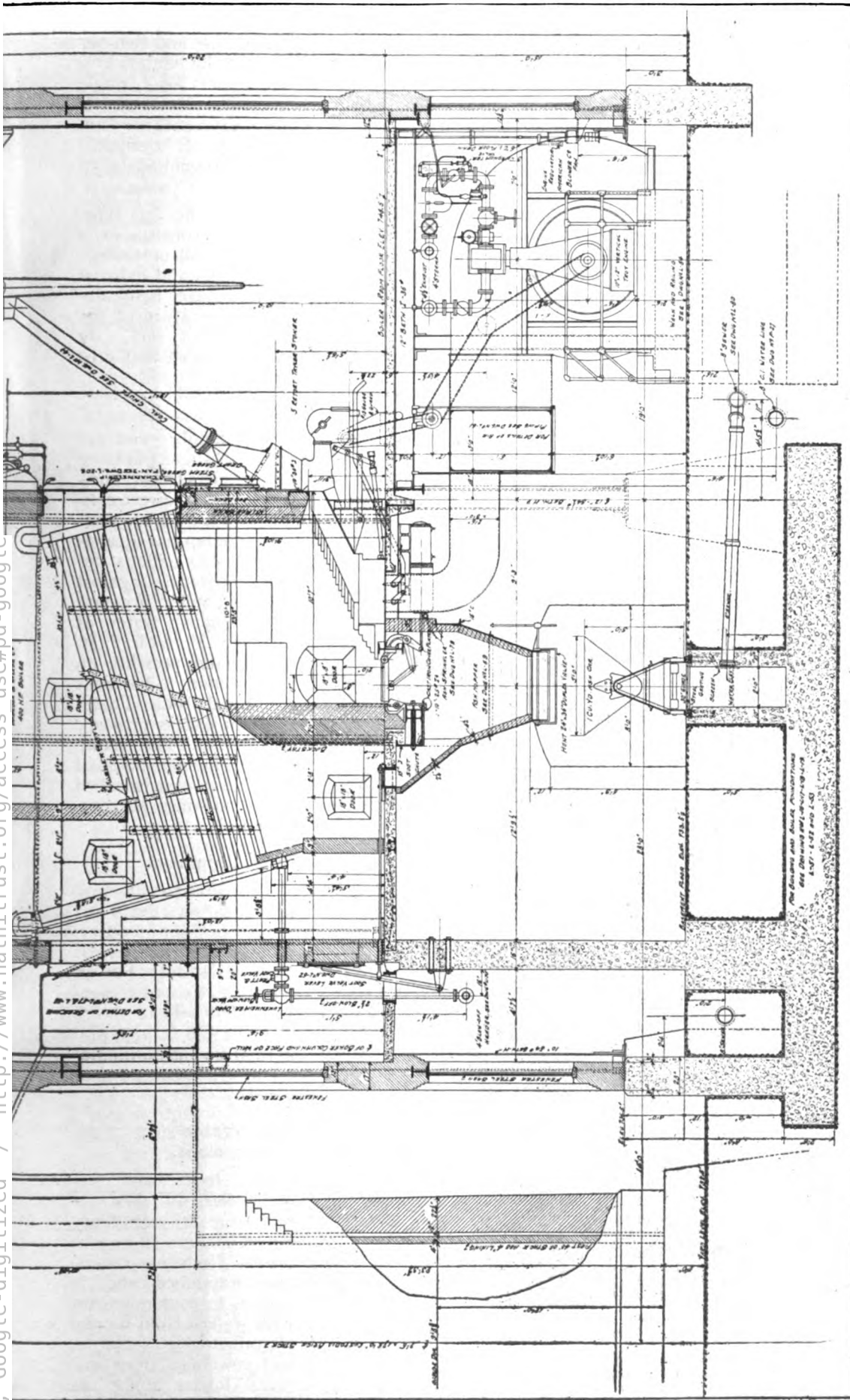


FIG. 7—CROSS SECTION THROUGH BOILER HOUSE

This drawing virtually tells the entire story of the steam generating plant in question. It is to be noted that the boilers are set 15 ft. above the ground line. This unusual height makes possible the desirable location of the ash hopper, of the fan and engines for driving same and for the air ducts. Ashes are very readily removed by means of this arrangement. Attention is also directed to the unusual height of the boiler setting. The front head of the boiler is 10 ft. above the floor line. The arrangement of the stoker and dump plate is clearly shown.

The burning fuel is gradually worked backward and downward, being pushed by fresh fuel, and when it finally reaches the dump plate practically nothing but hot ash and clinker remains.

This type of stoker is equipped with power dump which consists essentially of a steam cylinder located underneath the stoker, together with suitable mechanism connecting it to a dump plate of sufficient size and rigidity.

The dump plate is hinged and is supported at its free edge by a series of pawls set directly into the bridgewall, this to prevent sagging under load. By rocking these pawls, which are rounded so they do not lift the dump plate before releasing it, the dump plate is allowed to drop, and if the fuel contains little or no clinker, nothing else is required, but if the fuel contains clinker, as most soft coals do, part of this clinker forms on the dump plate and lower grate, and part is carried on to the face of the bridgewall where it tends to "hang" when the ashes are dumped; the power dump, however, acts as both hammer and scraper when raised above its normal position. After the ashes have been dumped, steam is admitted to the cylinder, and the slag crust on the bridgewall is scraped off, at one blow ordinarily, and the result is a clean fire, and no clinker building up on the bridgewall.

By referring to Fig. 7 we see the arrangement provided for ash disposal. As the ashes are dumped they fall directly into the ash hopper, bottom of which is closed by the 24x36 in. Hunt duplex ash valves, and as the occasion requires, the soot valve is opened from the rear of the boiler and the accumulated soot falls into the ash hopper through the soot chute.

After dumping, the operator opens a Haas automatic flush valve and a predetermined quantity of water is fed through the ash sprinkler, as shown on Fig. 7, quenching same, after which this ash is deposited in the ash car by opening the "Hunt valves," and then it is taken to the 20x20 ft. ash hoppers, shown on Fig. 3, and dumped.

Final disposal of ash is made by the Sprague grab bucket mono-rail crane, which handles the coal also, loading empty cars, which are spotted under the mono-rail on the coal track from the 20x20 ft. ash hopper.

Boilers.

Two 400-hp. Babcock & Wilcox horizontal

water tube boilers, sloping head, double deck, 18 tubes across, 6 rows in lower deck and 5 rows in upper deck, making a total of 198 4-in. tubes 18 ft. long and two 42-in. drums 23 ft. 6 in. long; and one 400-hp. Babcock & Wilcox horizontal water tube boiler, vertical head, single deck, 21 tubes across, 9 rows high, making a total of 189 4-in. tubes 18 ft. long and three 36-in. drums 20 ft. 4 in. long, make up the steam producing equipment. Sufficient space has been provided, however, to accommodate an additional boiler.

One 2,000-hp. National close, outside header type, feed water heater is used. This heater consists of a number of coils of tubing inclosed in a shell or casing; the feed water is pumped through the coils and exhaust steam is admitted to the shell. The feed water is usually raised to within 5 to 10 deg. of the temperature of the steam, resulting in a satisfactory saving of fuel. By referring to drawing, Fig. 3, it will be noticed that provision has been made for a second heater.

Feed Water Pumps.

The feed water pumps are two in number and are both Wilson-Snyder turbine driven centrifugal pumping units, consisting of a 3-in. two-stage, single suction, horizontal type Wilson-Snyder centrifugal pump, direct connected by means of flexible couplings to a 31.6-hp. non-condensing Terry steam turbine.

Each pump has a capacity of 130 gallons per min., operating against 150 lbs. boiler pressure and pumping water at 210 deg. F. with 7 ft. static water pressure on the suction. Turbines are fitted with Foster constant excess pressure governors. The pump and turbine are mounted on a heavy cast iron bed plate, making a complete unit.

Brick Chimney.

The forced draft fan, producing a draft of from 1 to 5 in. of water, relieves the chimney of most of its duty, but an Alphons Custodis perforated radial brick chimney 175 ft. high and 7 ft. 6 in. inside diameter at top has been provided.

Feed Water Treatment.

The feed water for our boilers is taken direct from the Allegheny River. This stream drains from an extensive watershed and is subject to contamination with waters from mines, manufacturing plants, and sewerage from various towns along its course. It, therefore,

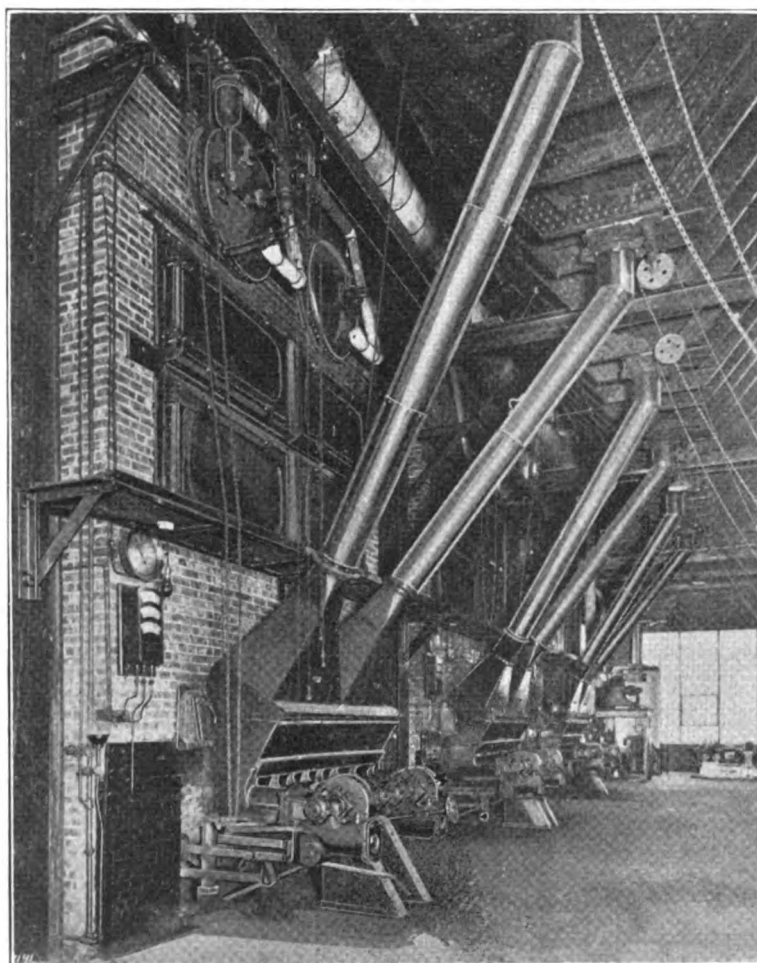


FIG. 8—INTERIOR VIEW OF BOILER HOUSE

A view down the firing aisle showing the plant as it appears at present. Suitable spouts lead from the rack and pinion type gates (controlled from the boiler house floor) on the bottom of the coal bunkers to the stoker hoppers.

varies considerably in its contained impurities. This is especially true after heavy rains. The tabulated analyses, given below, show just how changeable this river can be, these two analyses having been taken during different periods:

Turbidity	27.0	2.0
Suspended matter	53.0	2.4
Iron	1.5	.2
Silica	3.8	6.4
Calcium	7.4	26.0
Magnesium	1.6	6.0
Sodium and potassium	5.4	21.0
Bi-carbonate radical	24.0	71.0
Sulphate radical	12.0	30.0
Chlorine	6.0	32.0

Between the two analyses given above there is a difference in the principal scale forming constituents of 196 per cent in the carbonates and 150 per cent in sulphates.

Regardless of these changing qualities of the water from the river, our boilers are free from scale and corrosion. This is due to the scientific manner in which the chemical treatment of feed water is controlled, for which purpose we employ the services of Cyrus Wm. Rice & Company, Water Purification Engineers.

This control is affected through a co-operation between these engineers and our boiler room forces, by which the latter, each day, make and forward to the engineers the results of two simple tests of samples of water taken from the steaming boilers.

By this means we are advised just when a treatment is necessary. The service also insures us of the internal cleanliness of the boiler when steaming.

The chemicals required in treating the boiler feed water are dissolved within a chemical dosing tank of 250 gallons capacity located slightly above floor level in the basement of the boiler house. A small pump draws the soda solution from this tank and delivers same either into the main feed water discharge between the closed heater and boilers, or into each boiler. The object of the separate connections is to introduce an additional quantity of chemicals into any one steaming unit where the daily test readings indicate the necessity for such additional treatment. After a water is dosed with the chemicals, it is very important that representative samples be obtained of the boiler feed water before and after the treatment is added. For such purposes we collect one sample each of the raw and treated waters daily and one sample of water from each steaming boiler. All samples of raw and treated water are drawn uniformly over a 24-hour period into separate wooden containers located in the basement of the boiler house. At about the same time each day a 4-ounce sample of each of the above waters is taken from these barrels and placed into separate glass containers for collecting the weekly samples we forward the engineers for their laboratory analysis. This is done as a check on the boiler room force and on the effectiveness of the treatment within the boilers.

The sample of boiler water is taken after one of the regular daily blow downs from a ½-in. drip connection located on the blow-down pipe of the boiler. These blow-down samples are tested by one of our boiler men and results of the test reported direct by him to the engineers as above mentioned.

At the end of each month we receive a complete report showing the results of each test that was made by our boiler room forces and by the engineers. A copy of the report we receive is given herewith. (See Fig. 6.) Through such a record we can at any time check the

work of our own men and that of the engineers we hire for this purpose.

NATIONAL SAFETY COUNCIL PASSES RESOLUTIONS

Arthur H. Young, of the International Harvester Company, president of the council, in his annual address, August 28, at the Cass Technical High School, Detroit, made special reference to the comprehensive public safety program of the council and announced that a large sum of money had been made available by a group of insurance companies to aid the council in its campaign against automobile accidents. He placed particular emphasis on the value of its practical co-operation in as being a significant era in the progress of general accident prevention. He paid a tribute to the railroads in the Careful Crossing Campaign and to the hundreds of local safety organizations doing safety work in many cities through out the country. He prophesied that in time all preventable accidents will be prevented and that the people of the United States will take as jealous and watchful care of their lives and limbs as they now do of their dollars earned, saved and invested through fixed and ingrained habits of safety.

The congress adopted a resolution endorsing a safety platform for 1923 as follows:

Whereas, the 80,000 accidental deaths and millions of injuries occurring each year on our streets, in our industries, in homes and elsewhere are a blot on American civilization and the cause of untold suffering and sorrow, and

Whereas, the direct economic cost of industrial accidents alone exceeds one billion dollars annually, and

Whereas, experience has demonstrated that at least 75 per cent of industrial accidents are preventable and that approximately an equal reduction is possible as regards public accidents, therefore be it

Resolved: That the National Safety Council in its Eleventh Annual Congress in Detroit assembled advocates:

1. The safeguarding of all dangerous machinery and places according to standard methods of proved value;
2. The development of industrial equipment and processes along lines of inherent safety for the double purpose of eliminating accident hazards and increasing production efficiency;
3. The education of all workmen and their supervisors in safe methods and habits of work;
4. The training in safety of all school children, as well as students in colleges and universities, both for their own protection and as an object lesson in good citizenship;
5. The adoption and strict enforcement of uniform, practicable laws and ordinances for the safeguarding of vehicular traffic and the protection of the multitude of law abiding drivers and pedestrians against the thoughtlessness and recklessness of the few; and
6. The mobilization of all community forces through state and city safety councils for securing those ends through the overwhelming force of enlightened public opinion.

Iron and Steel Electrical Engineers Convention

The Sixteenth Annual Convention of This Society Held in the Cleveland Public Hall, September 11th to the 15th, Surpassed All Previous Meetings—Twenty-three Hundred Registered.

TWENTY-THREE hundred iron and steel electrical engineers and their friends registered for the sixteenth annual convention of the Iron and Steel Electrical Engineers held in the Public Hall, Cleveland, September 11 to 15. They were rewarded in many ways. The size and attractiveness of the exhibits in which 85 exhibitors showed their product, far surpassed any previous iron and steel electrical exposition. The technical papers were the most complete ever presented before this society. The convention hall, which was erected by the city of Cleveland at the expense of \$6,500,000, was particularly well suited for the convention, as it provided ample space in every way.

The annual banquet, held at the Statler Hotel, Thursday evening, was attended by approximately 500 engineers. The program for the banquet included such interesting speakers as Charles P. Steinmetz, chief consulting engineer of the General Electric Company; the retiring president, W. S. Hall, electrical engineer, Illinois Steel Company, South Chicago; J. S. Unger, manager of the Research Department, Carnegie Steel Company, and C. L. Collens, president, Reliance Manufacturing Company, Cleveland. H. P. Bope, formerly general sales manager of the Carnegie Steel Company, was toastmaster.

The Cleveland Section entertained the visitors Tuesday evening with a dance and an organ recital at the Public Hall. An interesting lecture on the "Science of Numbers" was given by E. Kieft, engineer of tests at the Gary plant of the Illinois Steel Company. At the business meeting Monday morning, Foreman R. B. Gerhardt, electrical engineer, Bethlehem Steel Company, Sparrows Point, Md., was elected president for the ensuing year. Other officers elected were as follows: First vice-president, L. F. Galbraith, electrical engineer, West Penn Steel Company, Brackenridge, Pa.; second vice-president, R. L. Shoemaker, superintendent of maintenance, American Rolling Mill Company, Middletown, Ohio; directors, A. C. Cummins, electrical superintendent, Carnegie Steel Company, Duquesne, Pa.; E. H. Wentz, electrical superintendent, National Tube Company, Lorain, Ohio; B. G. Beek, electrical engineer, American Sheet & Tin Plate Company, Gary, Ind.; George Schaeffer, electrical superintendent, Carpenter Steel Company, Reading, Pa., and A. L. Freret, assistant chief electrical engineer, Tennessee Coal, Iron and Railroad Company, Birmingham, Ala.; treasurer, John Farrington, electrical superintendent, LaBelle Iron Works, Steubenville, Ohio; secretary, John F. Kelly, Pittsburgh.

Dr. Steinmetz, during the course of his paper, said in part as follows:

"There are three ways of supplying power to an industry.

"The isolated plant without connection with any electric power system. The advantages and disadvantages of this arrangement have been discussed in the preceding. Where considerable energy is available as by-product of the industry, the cost of power from a local isolated plant may figure lower than power can possibly be bought from the central station. This, however, may have little meaning, as it depends on the value assumed for the by-product energy used as fuel by the local plant. If the by-product energy is not sufficient for the total power demands of the industry, additional fuel has to be used; where there is more by-product energy than required to produce the power, the surplus may be wasted, or an attempt made to find some other use for it. Or it may also be converted into electric power and some of the electric power sold. Or some industrial uses for the surplus electric power may be developed, such as electric smelting or refining. The latter probably is the most economical arrangement.

Or the electric power required by the industry may all be bought from an electric power system, and no local plant operated. This is most convenient, but depends on the rates which can be secured from the electric power company. In general, the power would be bought in bulk under a rate based on maximum demand and on power factor. It would therefore be economically desirable to arrange the industrial operation so as to have as nearly as uniform power consumption as possible, without large peaks of power consumption, so as to have the maximum demand exceed the average demand as little as possible and thereby to get the best rates. For power, synchronous motors should be used as far as possible, and operated over-excited so as to compensate for the lagging currents of induction motors. Power factor corrective devices, such as synchronous condensers, may be installed in the substation. The substation with its transforming, regulating, power factor controlling devices, etc., may be owned and operated by the power company, or by the industrial corporation, or it may be owned by the one and operated by the other. The power may be metered on the primary side of the substation, or on the secondary side. The general economic principle, I believe, should be that everything pertaining to power generation, transmission, transformation, control, etc., should be operated and preferably also owned by the power supply company, as being a legitimate part of the electric power industry; while everything pertaining to the application of the power to the specific industry served by the substation should

be operated by the industrial corporation. The specific arrangement which can be made will however to some extent depend on the financial strength, on the progressiveness of the management and the far sightedness of the engineering staff of the two companies.

If there is considerable by-product energy, some arrangement should be made to fully utilize this available energy. If the by-product energy is wasted entirely by not being used, or wasted intrinsically by being put to an inferior use, for heating only, instead of first taking out the available mechanical power, then the arrangement is uneconomical, even if financially the central station power supply should figure out an advantage.

"Where considerable by-product energy is available, and where central station power supply is possible from an electric power system, central station service may be combined with the operation of a local station.

"A part of the plant may be operated from the local station, another part by the central station power, leaving both electrically separated, but with arrangements whereby feeders may be connected over from the one service to the other. Or part of the time the plant may be operated from the local station alone, and central station power used only when the load exceeds the capacity of the local station. Or the connection to the central station may be entirely or essentially that of standby or emergency service, and normally the local plant supply all the power.

"Or the local station and the central station both may feed into the same set of local busbars, from which the power supply of the plant is taken. Various possibilities then exist in the arrangement of the load distribution between local and central stations.

"Power may be bought from the central station at unity power factor constant load, that is, unity load factor, and the fluctuation of load and the wattless current supplied by the local station. This would give the lowest cost (except off peak power) of the central station power, and therefore should give the best rates of power, those of continuous non-inductive load. It necessarily makes the local station operate less efficiently, and, where operated by by-product power requires sufficient storage facilities for such by-product power, to supply it at the rate demanded by the load fluctuations. Also, the generator armature and the generator fields may not be able to carry the excess current required in both to supply all the lagging currents of the system. This would have to be looked into.

"Or, instead of carrying all the load fluctuation and all the wattless currents by the local station, investigation may show it more economical to throw some load fluctuation and some wattless currents to the central station supply, when the gain in efficiency of operation of the local station, given thereto, is greater than the increase of cost of central station power. For instance, the central station rate may be the same for power factors from 90 per cent to unity, and then it would be of disadvantage to carry more wattless currents by the local station, than necessary to keep the power factor of the central station supply above 90 per cent.

"Where a daily or annual peak are a factor in the cost of central station power generation, and off peak power therefore of lower cost than continuous power,

lower rates may be secured if the plant operation can be organized so as to disconnect the central station supply for a few hours during the day, and operating on local power only. Or a two-rate metering may be arranged, that is, a lower meter rate during the off peak period. This would allow the use of central station power during peak load, if so required by the industry, but put a premium on avoiding it and securing the lower rate of the off peak power.

"Another way of operation would be, to carry constant load on the local station, and take the fluctuations by the central station service. In this case a less favorable price of central station power would result, but the local station would work at best economy. With by-product energy, the local station may then be operated at such output as to consume the byproduct energy at the rate at which it is produced, and eliminate the need of storage.

"The most economical arrangement between local station and central station power supply to a large extent depends on local conditions of power demand and supply, on the possibility of modifying the power demand to get more favorable conditions, and is deeply involved in the matter of rate making. While the economic principle of rate making is to arrange the price in proportion to the cost of power, as depending on quantity and quality (such as load factor and power factor, peak and off peak), the actual rates may not quite represent this, and the lowest rate may not always be the most economical."

GERMAN TECHNICAL BOOK REVIEW

By HUBERT HERMANN

L. Litinsky, *Wet-Cooling of Coke and Utilization of the Coke Heat*. (Trockne Kokskühlung mit Ausnutzung der Koksglut) 52 pages, 18 fig., 7 tables. Published 1922 by Otto Spamer, Leipzig. The different methods of utilizing coke heat are described, especially the method of using amorphous gases which utilizes the coke heat for generating steam in an economical way.

F. W. Hinrichsen and S. Taczak, *The Chemistry of the Coal* (Kohlenchemie) 3rd Edition, 523 pages. Published by W. Engelmann, Leipzig. The origin and the artificial production of coal; properties, distinction and classification of the natural coal according to its nature, microstructure, mechanical qualities and behaviour in heating; decomposition and self-ignition of coal; chemical and calorimetric testing of coal; the most economical utilization of fuels.

Edmund Schlosser. *Soldering and Welding* (Löten und Schweissen). A handbook for the practice; 257 pages, 81 fig., fifth edition. Published 1922 by A. Hartlebens Verlag, Leipzig and Vienna. Solders and soldering devices; the electric and autogenous welding.

Max Le Blanc, *Compendium of the Electro-Chemistry*. (Lehrbuch der Elektro-Chemie); ninth and tenth edition; 370 pages, 32 fig., published 1922 by Oskar Leiner, Leipzig. Development of the Electro-Chemistry during the 19th century; theory of the electrolytic dissociation of Arrhenius; determination of the ions; conductivity of electrolytes; electric endosmose; electromotive forces; electrolyse and polarization.

A. Schelest, *The Specific Heat of the Gases and Vapors* (Die spezifische Wärme der Gase und Dämpfe) 12 fig. Published 1922 by Franz Deuticke, Leipzig.

Judging the Combustion of Gaseous Fuels From Gas Analyses

By A. G. WITTING*

WE combustion engineers have a field of action of great importance. The consumption of fuel in a steel plant is enormous and the amount of potential heat value, carried by this fuel, that is not fully utilized should to us at all times seem to be too great. We should indeed be remiss in our endeavor if we did not consider the fuel practice obtained, even though relatively satisfactory, as standing in need of improvement; there is no doubt that even what is well done could be done a little better. In a plant like ours where up to 150 million cu. ft. of coke oven gas and between 800 and 900 million cu. ft. of blast furnace gas are daily produced and in addition over 2000 tons of coal are converted into producer gas the unavoidable losses represent a great money value; and in spite of the constant and conscientious efforts of the management to minimize it, the waste mounts high when translated into lbs. of coal equivalents. We are, all of us, trying our hardest to combat this condition, even if our efforts often show very discouraging results. But while it is only the practical results that count and theorizing often leads us to try to find excuses instead of remedies, nevertheless it is only through the correct application of theories (which themselves should be based entirely on practical results), that practical results are obtained. They are evolved from experience, but so many factors play in that the deductions drawn from this experience sometimes may stand in need of correction. It is, as I understand it, one of the objects of the Combustion Section of the Association of Iron and Steel Electrical Engineers to have its members bring such questions under discussion for the purpose of getting a better understanding of some of the phenomena that rule combustion.

The prime object of our work is to cut down fuel consumption, to obtain perfect combustion with a minimum surplus of air. In our pursuit of this goal we should, of course, direct our efforts to find improved methods and means for producing such a combustion, and there is a large room for improvement in the design of burners, furnaces, etc. But we should never lose sight of the fact that these are only tools, and that the handling of the same in the most efficient way is of greater importance, that the operator must know how to regulate his fuel and air supply, his furnace, burner or producer in as effective manner as possible. But the operator will not be able to do this unless he is familiar with the true theories governing his special problem of combustion. Whether he knows them or not, he will, if he is conscientious, get satisfactory results as long as everything is running normally, but if ignorant of these theories he will not be able to meet

an emergency. Proceeding from wrong conclusions, he is apt to apply the wrong remedy. He is like a man groping his way in a fog; as long as he travels his beaten path in familiar surroundings he will get on; but place an obstacle in his way that forces him out of his path and he is lost. It is up to us combustion engineers to spread the light that will penetrate the fog, but to do this we must know ourselves where the light is and how to handle it.

It might then be said that it is not so much normal as abnormal combustion conditions which should be the object of our studies. But the passage from a normal to an abnormal condition is gradual, and consequently not easy to detect by casual observation. We have nowadays at our disposition a great variety of measuring and recording instruments which are of a great help and which have done much to reduce fuel waste because they can tell us more accurately, than the eye, how everything is. They are as important to us as the barometer, the compass and the sextant to the skipper who, without them, would be lost.

But even though these instruments can tell us and the operator when a condition becomes abnormal, there are instances when we can not directly from them detect what caused this condition, which is the only thing that really counts. It becomes necessary for us to examine closer into the process of combustion, and the means at our disposition for such an examination is the old standby, the gas analysis.

It is my intention with this paper to discuss the significance of gas analyses or, more exactly, to advocate the better utilization of one kind of gas analysis, the waste gas analysis, and warn against the indiscriminate use of another kind, the producer gas analysis. In connection with this latter question I will also present some viewpoints on the important but often side-tracked function held by those constituents of the producer gas which, being condensable, escape our analyses, and lay before you the result of some investigations into the nature of these tarry vapors.

Waste Gas Analysis.

For metallurgical purposes the gaseous fuels are used: blast furnace gas, coke oven gas and producer gas. Their heat value and the efficiency of their combustion is judged from analyses and from the heat balance indicated by them; heat balance meaning the heat delivered to and usefully absorbed by the place of combustion, or the difference between the heat developed in the combustion plus the sensible heat in the gas and the air (if preheated) minus the sensible heat carried away by the waste gases.

A complete heat balance involves so many factors, that it to a large extent depends on guess work or arbitrary assumptions—its value is consequently, to say the least, questionable. To make up such a heat balance, for example, for a hot blast stove gas burner,

*Assistant Chief Engineer, Illinois Steel Company, Gary, Ind.

Abstract of paper presented at convention of Iron and Steel Electrical Engineers. Complete papers and discussions can be secured from J. F. Kelly, Empire Bldg., Pittsburgh, Pa.

it is necessary to obtain not less than nineteen items of information, each requiring a series of observations taken during the same time. I am tempted to say that such a feat has never been really accomplished. But on the other hand, the efficiency of the combustion, itself, the more or less correct manner in which the fuel and its air supply is handled by the operator, can be judged exactly from an analysis of the gas and an analysis of the products of combustion, provided that both samples are taken simultaneously, not the one immediately after the other.

It is clear, that the highest efficiency is developed when all the combustibles in the gas and all the oxygen in the air are consumed, leaving in the waste gases nothing but CO_2 , N_2 and H_2O . This means a 100 per cent reaction and is in practical operation not attainable. The fuel is burnt either with an oxidizing flame, with a surplus of air, indicated by the presence of oxygen in the waste gas analysis, or with a reducing flame, the air supply being below requirements so that combustibles are carried away with the waste gases and appear in their analysis. It also happens that both oxygen and combustible gases at the same time occur in the waste gases. In the latter two cases a direct comparison between the two analyses is not possible, the composition of the waste gases can not be calculated directly from the gas analysis. Under these conditions it has been customary to figure the waste gases produced on the assumption that all the carbon in the original gas is found in the waste gas, the volume of the latter comparing with the volume of the former as the CO_2 that would have been produced by complete combustion compares to the CO_2 in the waste gas analysis plus the CO_2 that would have been produced by the unburnt combustibles.

Now, very often in metallurgical operation the waste gases contain CO_2 which is not derived from the fuel. When this occurs there exists, at least to the writer's knowledge, no published method by which the combustion process can be calculated. It is the purpose of this paper to set forth a series of simple formulas which will assist in solving such problems.

Complete Combustion.

For the numerical examples introduced in the paper or in the appendices attached to it I have been using the standard values for chemical reactions. As a help to anybody who may want to check my calculations I have collected these values in a table which appears in Appendix No. 1.

I have assumed that the air by volume contains 21 per cent oxygen and 79 per cent nitrogen, and that accordingly one cubic foot of oxygen in the air is associated with 3.762 cubic feet of nitrogen, making 4.762 cubic feet of air. The high, or gross heat values are used for blast furnace gas and coke oven gas, because corroborative calorimetric tests are generally made with these gases. For producer gas the lower or net values are mostly used, as this gas is not tested by calorimeter. This is, of course, not a rule laid down, only an explanation of my method of calculation.

To determine the efficiency of a burner or a furnace operation we have obtained our two gas samples, the waste gas sample being collected at a point where any danger from outside influence, air leakage for example, is as far as possible eliminated. If the analysis of the waste gas does not show any combustibles present, the chances are that oxygen is found. The question then naturally is: how much surplus air has been admitted? It will be necessary first to calculate the

requirements and results of a theoretically perfect combustion. Having thus obtained the volume of the products of combustion, neglecting the condensable moisture, the amount of air present in the waste gases, as indicated by a certain percentage of oxygen and the total volume of waste gases, is obtained by means of the following formulas:

$$(1) \quad A = \frac{Pa}{21-a} : W = \frac{21P}{21-a}$$

When A = amount of surplus air.

P = products of complete combustion (minus moisture).

W = total amount of waste gas = $A \div P$.

a = percentage of oxygen in waste gas.

Appendix No. 2 gives an example of such a calculation when the fuel was blast furnace gas. 100 cubic feet of this gas required 71.43 cu. ft. of air and gave 153.43 cu. ft. of waste gases (not counting the H_2O). The waste gas analysis showed 1.8 per cent oxygen, which meant that the waste gases contained 14.38 cu. ft. surplus air corresponding to a surplus of 20 per cent that the total amount of waste gases produced from 100 cu. ft. of gas was 167.81 cu. ft. to which, of course, has to be added the amount of water vapor calculated from the gas analysis plus the moisture contained in 100 cu. ft. of gas and 85.81 cu. ft. of air.

Incomplete Combustion.

The usual method of figuring the volume of the waste gases when the combustion has been incomplete, from the carbon contents does not need any demonstration here because this method, as stated in the introduction, can not be employed if any carbon dioxide has been added to the waste gases from any other source than the fuel gas itself, as usually is the case in an open hearth furnace. Besides, it offers no advantages over the one I am going to submit and which is based on the air present, whether used for combustion or left as a surplus in the waste gases. The formula may appear unwieldly and downright formidable. But in the by far greater majority of cases most of the factors in the formula will be eliminated as not appearing in the analysis.

Composition of Fuel Gas Analysis		Composition of Waste Gas Analysis		Volume
CO_2	a%	CO_2	h%	hw
C_2H_4	b%	C_2H_4	j%	jw
CO	c%	CO	k%	kw
H_2	d%	H_2	l%	lw
CH_4	e%	CH_4	m%	mw
C_6H_6	f%	C_6H_6	n%	nw
N_2	g%	N_2	p%	pw
O_2	o%	O_2	q%	qw
H_2S	s%			
	100%		100%	100w

$$(2) \quad w = \frac{y + v - o}{x + z - q} \quad \text{if } x = \frac{21}{79} p; \quad v = \frac{21}{79} g$$

$$y = 3b + \frac{c}{2} + \frac{d}{2} + 2e + 7\frac{1}{2}f + 1\frac{1}{2}s$$

$$z = 3j + \frac{k}{2} + \frac{1}{2} + 2m + 7\frac{1}{2}n$$

After the volume of the waste gases in this manner has been established, other information wanted is obtained by the following equations:

$$(3) \text{ Air present: } A_p = \frac{100 (pw - g)}{79}$$

$$(4) \text{ Surplus air: } A_s = \frac{100 q w}{21}$$

$$(5) \text{ Air needed for complete combustion—} \\ A_c = \frac{100 (y - o)}{21}$$

$$(6) \text{ Useful air:} \\ A_u = A_p - A_s = \frac{100 (y - zw - o)}{21}$$

$$(7) \text{ CO}_2 \text{ addition} = w (h + 2j + k + m + 6n) \\ - (a + 2b + c + e + 6f)$$

In Appendix No. 3 the derivation of the formulas is explained and the application of the same is illustrated by a couple of examples with check-ups which prove the correctness of the formulas.

As it is not necessary, when using this method for calculating the waste gases, to figure the results of a theoretical combustion, but it always is required to know the amount of water vapor produced, the same will be obtained by means of the following formula:

$$(8) \text{ H}_2\text{O} = (2b + d + 2e + 3f + 2s) - \\ w (2j + 1 + 2m + 3n)$$

With the assistance of these formulas any waste gas analysis, no matter what it contains or in what manner the CO_2 has been produced, can be translated into cubic feet, providing an analysis of the fuel gas has been taken simultaneously with the waste gas analysis. It is, consequently, no longer necessary to arrive to your deductions by guessing. You will know positively how great a percentage of the combustibles in the gas has passed unconsumed through the furnace or how great the surplus of air has been or what percentage of the CO_2 has been added to the gases from the material in the furnace. In this way it will also serve as a check on the analysis itself.

Producer Gas Analysis.

As just stated, it is at all times necessary to give proper attention to the amount of condensible matter in the gases which the analyses unfortunately neglect. This necessity becomes still more important when the question is of producer gas which always carries in addition to water vapor a certain amount of so-called tarry vapors, products of the distillation of the volatile matter of the coal, which can not be analytically determined. Writers on the subject generally satisfy themselves with calling attention to their existence and then forget them, continuing the discussion as if producer gas was non-condensable like blast furnace gas or coke oven gas.

It is the object of the following part of the paper to make clear how erroneous the conclusions might be which are drawn under the assumption that the ordinary producer gas analysis shows up a hundred per cent of the gas generated from the coal in the producers.

The writer has given this phase of the fuel problem considerable study and succeeded to construct from analyses the probable composition of the volatile matter in Indiana Coal from the Clinton district. It would require too much space, and be partly outside the subject, to repeat in detail the methods employed; and I

will, therefore, content myself with saying that a double cross-checking of the result obtained, verified the same remarkably well.

The laboratory analysis of the coal in question gives the following composition:

Volatile matter	35.51%	Ultimate Analysis	
Fixed carbon	48.28	Total carbon	67.91%
Ash	9.41	Hydrogen	4.57%
Moisture	6.80		
	100.00%		

The constituents of the volatile matter determined by a series of analyses and with the assistance of analogies from analyses of similar coals made by the Bureau of Mines were as follows:

Condensable hydro-carbons	10.052%
Permanent gases	18.262%
Neutral condensates, H_2O and H_3N	7.196%
	35.510

Our method of taking producer gas samples is to collect them unknown to the gas makers regardless of the conditions of the producers, so as to get as true an average as possible and not—as too often is the case—a series of analyses that look very attractive on paper but mean nothing to the one that supervises the operation of the producers.

Selecting, for the purpose of proving my suspicions, with regard to the true value of an analysis, the latest 50 analyses taken as a daily routine work at our open hearth furnaces, I obtained an average composition of the gas produced from this coal of:

CO_2	8.0%
C_2H_4	0.4%
CO	20.3%
H_2	8.1%
CH_4	2.6%

The average low heat value was 118 Btu.

Appendix No. 4 gives more in detail the composition of the coal and the composition of the gas.

The gas is, as everybody knows, produced from the coal partly through direct gasification of the fixed carbon by the blast (a mixture of air and steam) and partly through distillation of the volatile matter. In addition, secondary reactions of varying nature have taken place, stabilizing the hydrocarbons in the volatile matter into gases that are permanent in heat. These processes may be considered either as a series of pyrogenetic reactions, whereby the hydro-carbons, at the high temperature prevailing, are condensed into higher compounds and free carbon, or cracked up into more simple non-condensable compounds and free hydrogen, or else as direct reactions between the hydro-carbons and the distillation products (particularly CO_2 and H_2O and, of course, oxygen if due to a thin fuel bed or channels in the same, the oxygen has not all been absorbed in the gasification zone), forming CO and H_2 . A true understanding of these reactions are of highest importance in the correct operation of a producer and they offer a wide field of study which, however, is outside the scope of this paper. I will, therefore, content myself to call the attention to them.

In considering the influence of these secondary reactions on the composition of the gas, we might assume three possibilities:

1. That only the first kind of reactions takes place, viz: that all the tarry vapors enter the gas as stable hydro-carbons
2. That only the second kind of reactions takes place, viz: that all the tarry vapors are broken up and converted into permanent non-condensable gases, so that the gas analysis represents hundred per cent of the gas produced.
3. That both kinds of reactions occur simultaneously, the preponderance of the one or the other, depending on operating conditions, but with the result that the gas always contains some condensable hydro-carbons and the gas analysis consequently does not represent all the gas.

It being generally conceded that the gas receives its luminosity from the hydro-carbons and that this luminosity is of highest importance, at least in open hearth practice, it follows that the quality of the gas is improved to the degree in which the first kind of reactions dominate.

Now, there may exist a difference of opinion on this question, in a paper recently read before the American Society of Mechanical Engineers not only the need of luminosity in gas used at open hearths was questioned, but the author tried to prove that the tarry vapors in the gas had nothing with the luminosity to do. But I take the stand that luminosity is a necessity and that while luminosity might be obtained in other ways, it is imparted to **producer gas** practically altogether from the hydro-carbons in the gas which dissociate in the flame precipitating solid carbon, which not only when brought to a white glow gives off a dazzling light but being equal to the so-called "perfect black body," possesses greater radiating power than any other solid. The author referred to presents some figures to prove "that the illuminants in the gas are non-essential." Now, against this statement I want to call your attention to the fact that, as everyone unfortunately is fully aware, the waste gases from a fire where coal or a gas produced from coal is the fuel, might issue from the stack as a dense black smoke. This color of the smoke is due to soot or carbon particles dissociated from hydro-carbons in the flame, but for one reason or other cooled below their ignition point. No matter how bad the combustion, it must be assumed that never 100 per cent of the carbon in the gases leaves the combustion chamber unconsumed, that, in other words this soot in the waste gases represents only a **fraction**, even if it is a large one, of the carbon present in the flame, and there heated to the temperature of the flame. It is claimed that the actual carbon in dense black smoke amounts to 1 per cent of the carbon in the coal and that this carbon under the microscope appears as clusters of small particles about 0.000002 in diameter.

I think everybody will agree that these clusters, or visible smoke particles, will pass through a hundred-mesh sieve, if they are not smaller. It is easy to calculate that under this assumption every cubic foot of waste gas at the top of the stack (temp. = 300 deg. F.) would contain about 5,400 such particles, evenly distributed in the gas. Assuming on the other hand a producer gas of ordinary quality or one with half of its tarry vapors destroyed in gasification (about which more later on) and that one-half of the remaining tarry vapors are lost in the mains and checker chambers, which is an extravagant assumption, then in the combustion of this gas with air in excess creating a tem-

perature of 3,300 deg. F. each actual cubic foot of the gas mixture in the furnace will according to the same method of calculation, contain about 4,400 such carbon particles, pretty near as many as those which in a cold state were able to color the waste gases black. The open hearth furnace chamber would then hold about 15,000,000 incandescent specks of carbon emitting a brilliant white light; and I am sure that it could safely be assumed that they would produce some luminosity. Without a question of doubt, the carbon particles in the gases in the furnace are many times smaller and coagulate to the visible size in which they appear at the top of the stack during the passage through the flues, and consequently it may be assumed that the number of luminous specks in the furnace chamber is too large to be expressed in figures.

Having made this digression to strengthen my statement that the producer gas receives its luminosity from the hydro-carbons, I might take up the argument where I left off and say that it follows that the quality of the gas is improved to the degree in which the tarry vapors in the volatile of the coal are converted into stable hydro-carbons. The question then presents itself: Can the ordinary gas analysis tell us whether the hydro-carbons are more or less preserved in the gas?

I am sure that the majority of combustion engineers will answer: "Yes, the higher Btu. in the gas, the higher is its quality." This is probably correct in a general way, but I claim that it is not necessarily so, and that very often a gas with a fine looking analysis is defunct in hydro-carbons. In other words, I claim that it is absolutely impossible to tell from the gas analysis whether the hydro-carbons in the tarry vapors have been preserved or destroyed.

To prove this statement I have set forth in Appendix No. 5 a series of detailed calculations based on the analyses of coal and producer gas which I quoted before. You will see from these calculations that the very same analysis can be obtained whether **all** the hydro-carbons have been destroyed and converted into fixed gas, whether they are all preserved but stabilized or whether part of them are destroyed and part of them preserved. The gas produced from one pound of coal according to the one or the other condition might have identically the same analysis, but its physical properties are decidedly different as the following table will show:

GAS PRODUCED FROM ONE POUND OF COAL

	Cu. Ft. Fixed Gas	Cu. Ft. Tar Vapors	Cu. Ft. Water Vapor	Total Cu. Ft.	Btu. per Cu. Ft.	Total Btu..
Case 1:						
All tar vapors destroyed ..	66.3	...	9.1	75.4	103.7	7822
Case 2:						
All tar vapors preserved ..	56.9	0.3	9.3	66.5	127.7	8490
Case 3:						
50% tar vapors preserved ..	61.9	0.15	9.2	71.0	114.9	8156

Not only is the total heat value, obtained from one pound of coal, considerably lessened as the tar vapors are cracked up and fixed but, what is very much more important, the actual heat value per cubic foot when the moisture is considered, is in reality not 118 Btu. but might be as high as 127.7 Btu. or as low as 103.7 Btu. And to this you must add the heat transfer capacity, the radiating power of the gas, which, as I

hope I have proved, depends entirely on the tarry vapors preserved, or more correctly, on the amount of condensed hydro-carbons contained in the gas.

No doubt, the majority of combustion engineers has some time been puzzled by the apparently anomalous fact that a gas having a good analysis burnt with a thin flame lacking "body" while another furnace had a sharp, quick-working flame, although the gas analyzed lower. The data presented here ought to give a satisfactory explanation to such puzzles and substantiate my claim that the analysis of the gas does not offer any indication of to what degree the tar vapors remain in the gas. It might be possible, although highly improbable, that the gas production has followed the lines of Case No. 1 with all the vapors reduced to fixed gas. Again it might be possible, although just as improbable, that all the tarry vapors, according to Case No. 2, remain as hydro-carbons in the gas. Neither is there anything to warrant the assumption that the gasification takes place exactly according to Case No. 3 on a fifty-fifty basis. It might be 75 per cent or more either way. But as long as any assumption has to be made, this condition might just as well be accepted because, as shown in the following, it offers some simple figures to be used in the calculations, and it is close enough so that the results of the calculations need not be misleading.

The question naturally presents itself: If the quality of the gas chiefly depends on the presence of hydro-carbons and the gas analysis can not tell anything about it and consequently is not a dependable indicator of the quality, what is then the use of a gas analysis? My answer is, that gas analyses are nevertheless very useful, as long as they are used with discrimination. They are, to begin with, indispensable in any calculations concerning combustion. They will, furthermore, give a good relative comparison of the operation of the individual producers in a plant where the producers are of the same type and operate on the same kind of coal. Besides, it is possible by means of gas analyses, if taken in a certain way, to determine the real quality of the gas, viz: whether the majority of the hydro-carbons are destroyed or remain in the volatile.

In a gas producer of the usual design the secondary reactions cracking up the hydro-carbons into fixed gas, are generally caused by CO_2 and H_2O attacking the hydro-carbons forming CO and H_2 according to the simplified formulas: $\text{CH}_4 + \text{CO}_2 = 2\text{CO} + 2\text{H}_2$ and $\text{CH}_4 + \text{H}_2\text{O} = \text{CO} + 3\text{H}_2$, in which formulas any paraffin can be inserted in the place of CH_4 . These reactions occur probably at all times to some extent, but to make them really destructive the CO_2 and H_2O must be present in excessive quantities, which will happen when the fuel bed is thin and full of holes and channels. The steam-air blast will not have time to function properly; the gasification will be very uneven and the gas, in spots, contain principally CO_2 , undecomposed H_2O and even oxygen. It is this gas rising through the channels that destroys the hydro-carbons and give the gas, when sampled in the main, the false appearance of being the result of a good gasification although the contrary is the case. The correctness of this theory we have proved through a series of gas samples collected inside the producer about a foot above the fuel bed, three short-time samples being taken simultaneously, one close to the side, one at the center and one half way in. As the time does not permit any detailed discussion of the very interesting results of the test, I will content myself with saying

that the test covered all conditions possible, the fuel bed being deliberately allowed to take care of itself; that is to say, the producer was run at the ordinary rate without any poking, and with intermittent filling, so as to get an uneven fuel bed. It was found that when the producer was in a normal condition the three sets of samples averaged about the same, but that when channels were formed the sample from the periphery or the one from the center, and sometimes both, analyzed very low. Out of 155 sets of samples or 465 samples in all, 136 had a heat value below 80 Btu. and 82 less than 50 Btu. Of these 82 samples 67 had very high CO_2 contents, an average of 15.4 per cent, 5 had an average of 16.7 per cent O_2 and 10 about the same amount of CO_2 and O_2 (average 8.3 per cent CO_2 and 7.5 per cent O_2); in neither could any dissociation of steam have occurred. Comments are really superfluous; a gas of such a composition even though coming only from a small part of the fuel bed surface will necessarily have a disastrous influence on the volatile matter distilled off from a considerable area adjacent to the hole in the fuel bed.

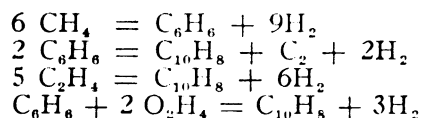
Testing individual producers in this manner with three simultaneous samples at various points inside the producer will, without question, tell the condition of the fuel bed and the quality of the gas. We have found this method of testing to have a distinct practical value, particularly for mechanical producers. For example, having once reasons to suspect that the gas from a set of producers, although its analysis apparently was satisfactory, yet lacked in quality, gas samples were taken from all the producers in this manner. The center samples from one of the producers showed a very low Btu. value, indicating a thinner fuel bed at the center, due obviously to faulty coal distribution. The distributor was examined and a corner was found to be broken off; after repairs had been made the quality of the gas was restored to its normal high mark.

But while it thus is possible to judge the presence of the tarry vapors in the gas from gas analyses, the method imposes additional work on the laboratory and is not suitable for everyday routine work. I would, therefore, suggest the desirability of adopting another standard from which the quality of the gas could be judged. Formerly illuminating gas was measured by its candle power. With the advent of gas mantles and gas stoves the value of the illuminating power became of no consequence, while the heating power determined the quality of the gas, and the specifications were changed so that they stipulated a certain Btu. value for the gas, omitting any mention of the candle power. Reversely, I think that the producer gas should be judged by its luminosity and not by its heating value, at least where open hearths are concerned. It certainly would be a great help to the combustion engineers, if an instrument were designed that could measure directly the luminosity or the radiating power of the producer gas.

But returning to the discussion of the condensible hydro-carbons, which are distilled over into the gas, they consist, whether all or only a fraction remain in the gas, of tarry vapors and benzene with a constant percentage of carbon and hydrogen for a given kind of coal.

It is indeed an interesting coincidence—if nothing else—that the hydro-carbons in the coal which I have taken as a basis for my calculations, closely correspond in composition to naphthalene, C_{10}H_8 , because accord-

ing to all authorities, naphthalene is the predominant hydro-carbon compound that **remains** after the gas has been subjected to heat. It is itself not affected by any pyrogenetic reactions but is on the contrary the result of such reactions on other hydro-carbons. Professor Berthelot of Paris, the greatest authority on the subject, has among other pyrogenetic reactions produced the following ones:



In Appendix No. 6 I have set forth more in detail the figures proving this statement and calculations of the true volume of the waste gas from analyses when the presence of the condensible hydro-carbons are taken into account. From them is seen that while the tarry vapors in actual volume only represent one-quarter of one per cent, they nevertheless are responsible for 11 per cent of the heat value in the gas and for nearly 7 per cent of the waste gases.

Any calculations as to the products of combustion based on gas and waste gas analyses, would accordingly be misleading unless due consideration is given the tarry vapors. The exact amount of course we have no means of determining, but the assumption that, when the producers are operating normally, at least one-half of the tarry vapors are preserved in the gas will give a fairly correct result.

When applying the general formulas, that I presented in Section 2, to producer gas, the following corrections should be made:

$$\text{Formula 2 } w = \frac{y + v - o + 3}{x + z - q}$$

3 (cu. ft.) represents the amount of oxygen required by the tarry vapors per 100 cu. ft. dry gas.

$$\text{Formula No. 7: } \text{CO}_2 = w (h + 2j + k + m + 6n) - (a + 2b + c + e + 6f) - 2.5$$

2.5 (cu ft.) represents the amount of CO_2 produced from tarry vapors.

The necessity of entering the true volume of the water vapor in the waste gases into the calculations offers another difficult problem as it can not be determined directly, but involves a knowledge of the ultimate analysis of the coal and the amount of air used in gasification. It will never do arbitrarily to assume a value of the moisture that is contained in the producer gas and it is possible to derive at a figure that is sufficiently close so as not to introduce any perceptible error in the calculations. With regard to the moisture resulting from the combustion, one cubic foot should be added to the amount obtained through formula No. 8, this one cubic foot representing the water vapor produced by the combustion of the tarry vapors.

In conclusion I want to call attention to another fact which often is overlooked; the necessity of **two** waste gas analyses when the problem concerns the combustion in an open hearth furnace, the question being whether the ratio between the gas and the air is correct or whether the combustion is performed in a satisfactory manner. When problems of this nature, involving the combustion in the furnace proper, are to be solved by means of gas analyses it will abso-

lutely not do to collect the waste gas sample in the flue between the reversing valves and the stack because there always is a leakage of air into the downtakes and checker chambers and because there might be a short circuit in the gas reversing valve introducing combustibles in the waste gas. The sample must be taken as close to the furnace proper as possible—in the ports or downtakes. But due to the construction of the furnace, where the air and gas currents are introduced one above the other on more or less parallel lines and removed in a similar way, a perfect mixture is seldom obtained. A certain amount of gas will sweep closely over the bath; a certain amount of the air sweeps along the roof; between them is a separating blanket of waste gases and the result is that combustibles will show up in a waste gas sample collected from the gas downtake, while a simultaneously collected sample from the air-downtake shows free oxygen, indicating surplus air. Under normal operation, when the ratio between gas and air is close, this condition is more the rule than an exception. If only one sample is taken, either from the air or the gas downtake, the result must be **erroneous**; unless one sample from each of the downtakes is taken, simultaneously with a fuel gas sample (the sampling time of course in all three cases being inside a reversal or not more than 10-15 minutes) it is useless to attempt any calculations. It is naturally pre-supposed that the ratio in which the waste gases divide between the gas and air ports has been established by observations. This ratio is probably different from every furnace. In the calculations presented in Appendix No. 7 I have used a ratio of 45 per cent going through the gas ports and 55 per cent through the air ports, figures that we have obtained from actual measurement. These calculations show that the total amount of waste gases produced was 232.118 cu. ft., that the surplus of air was 10.4 per cent while the useful air amounted to 96.4 per cent of the air necessary for complete combustion. The ratio of heat development will figure to be 95.85 per cent. If we had contented ourselves with one waste gas analysis, we would have gotten, if we had taken our sample in the air port, 249.374 cu. ft. waste gases (or 7.4 per cent more than actually produced) as a result of complete combustion with a surplus of air as high as 27.2 per cent while, if the sample had been secured from the gas port, the result would have shown 214.018 cu. ft. waste gases (or only 92.2 per cent of the actual amount) with only 91.5 per cent of the possible heat developed because only 92.7 per cent of the necessary air were present.

It may seem inconsistent first to point out the mistake often committed by introducing assumptions in the calculations and then to try to prove my argument against ordinary producer gas analyses by means of an assumed quantity of tarry vapors existing in the gas. But my object was to show the great importance of the tar vapors not to produce a heatbalance. In the problems of combustion with which most of the time we have to deal, the question is not about the actual volumes nor of the total heating value, but simply whether the combustion is going on in an efficient way, and whether the proportion of gas and air is satisfactory. The calculations carried out according to my method and based on waste gas analyses collected at the gas port as well as at the air port **simultaneously** with a fuel gas sample will, under these circumstances, give a sufficiently close result, even though the presence of tar vapors and water

vapors is neglected, particularly as the analyses are presented with only one decimal and it is perfectly satisfactory to compute the figures, on which the judgment is based, with one decimal only.

It has been the purpose of this paper to call your attention to the fact, that any guess-work can be eliminated from the solution of ordinary combustion problems by means of waste gas analyses, and to present a method that will extend the possibility of their application as it will establish the relations between a fuel gas and the waste gases even when the combustion is incomplete and part of the CO_2 is derived from the metal bath. I have confined myself to gaseous fuels, but the formulas can easily be modified to apply to liquid fuels as well, provided the assumption is made that they, during a certain stage of the combustion process, are gasified and dissociated into their elements. This assumption is of course in reality wrong, but as a purely theoretical chemical proposition it is permissible as the final result of the calculations will be the same.

It has furthermore been my intention with this paper to point out the error so commonly committed in judging the quality and the heating value of producer gas entirely from an analysis of the fixed gases it con-

tains, neglecting the tarry vapors, something that should not be excused with the inability to determine their amount. What is required is, that side by side of the gas analysis another standard be placed, based on the luminosity (candle power) of the gas. Should I have succeeded in convincing you of the soundness of my arguments and turning your attention towards this new direction, we will undoubtedly in a short time have a practical apparatus that will gauge the contents of tarry vapors in producer gas; and another step would then be taken forward to a more efficient application of fuel for metallurgical purposes.

TABLE 1—TABLE OF CHEMICAL REACTIONS IN COMBUSTION

One Cu. Ft.	Requires in Cu. Ft.		Produces in Cu. Ft.			Btu. Developed per Cu. Ft.	
	Oxygen	Air	CO_2	H_2O	N_2	High Value	Low Value
C_2H_4	3.0	14.286	2.0	2.0	11.286	1591	1491
CO	0.5	2.381	1.0	..	1.881	324	324
H_2	0.5	2.381	..	1.0	1.881	328	278
CH_4	2.0	9.524	1.0	2.0	7.524	1012	912
C_2H_6	7.5	35.715	6.0	3.0	28.215	3810	3494
C_2H_2	2.5	11.905	2.0	1.0	9.405		1437
C_3H_8	12.0	57.144	10.0	4.0	45.144		6070
H_2S	1.5	7.143	1.0(SO_2)	1.0	5.643		

Internal Combustion Engines for Power Generation in Steel Plants

By D. M. PETTY*

THE internal combustion engines which will be described in this paper are the 4-cylinder, 4-cycle double acting gas engine and the 4, 6 or 8-cylinder, 2-cycle Diesel oil engine. The discussion in general will not go into thermo dynamic theory to any great extent, but will rather cover a general description of some of the mechanical features as well as the operation of the two types of engines, together with some analysis of first cost and cost of operation.

The Gas Engine.

The gas engine which forms the basis for this discussion is rated 4,000-kw. output of generator running at 88.3 rpm.

The floor space occupied is 68 ft. long and 37 ft. 6-in. wide; two cylinders are in tandem and connected to each end of the crank shaft. The distance between center line of cylinders is 27 ft. 8 in. It carries a very heavy cast steel flywheel made in two parts, the diameter of which is 28 ft. and weight 130 tons. The cylinders are 47 in. diameter. The piston has a 60-in. stroke; they are made of cast steel. In this particular size the cylinder is usually made in two pieces; however, in this size as well as in similar smaller sizes one-piece cylinders have been found entirely satisfactory.

*Electrical Engineer, Bethlehem Steel Company, South Bethlehem, Pa. Paper presented before Association of Iron and Steel Electrical Engineers, Cleveland, Ohio, September 11-15. All discussions on this paper may be secured from J. F. Kelly, Secretary, Empire Building, Pittsburgh, Pa.

In case of power cylinders of this size, steel rather than cast iron is employed because in order to maintain the same factor of safety the wall of the cast iron cylinder must be much thicker than if cast steel be used. The cast iron wall must on account of strength be made of a thickness so great that it cannot transmit the requisite heat per unit of surface. The consequent difference in temperature between inner and outer surfaces of wall induces heat fatigue and consequent cracks when engines are steadily operated at full load. A cast iron cylinder which thus cracks cannot be repaired by welding. A cast steel cylinder seldom cracks and if it does, can be electric welded without any difficulty. We have steel cylinders in our plant that have operated continuously 13 years and are still perfectly good.

The piston rod is 15 in. in diameter and is hollow, making a convenient opening through which the cooling water is carried to the piston. The crank shaft is a one-piece forging and the crank disc and crank pin are cast steel and made in one piece. The cross-heads are also cast steel; the inlet and exhaust valves are one-piece forgings.

A great many of the above mentioned parts are frequently made of cast iron, but in the steel business cast steel is favored for obvious reasons, and since this engine is built by a steel company, cast iron is replaced by cast steel for a great many parts.

The speed of this engine is controlled by a spring

weighted governor which operates an oil relay. This relay provides ample power for moving the valves, no matter whether they are clean or dirty, and is a very important item in the satisfactory operation of any engine used in the generation of power.

An automatic gas pressure regulator is located just ahead of the inlet valve and maintains a constant gas pressure of 2 in. at the inlet valve. The air mixture is adjustable, but is maintained constant throughout any range of load from zero to maximum unless adjusted by hand, the power output of the engine being governed by throttling the mixture of gas and air rather than by adjusting its richness. The maximum pressure in the cylinder after explosion is 275 lbs.

Fig. 1 shows a typical set of indicator cards on one of these engines.

The gas is ignited at the proper time by three spark plugs which operate on the make-and-break principle, 110 volts being the voltage and the current about .75 amperes. This current is limited by the resistance of the winding on an iron core solenoid which gives a long inductive arc, a small incandescent lamp is connected in series with the coil which serves to indicate the condition of the spark plugs.

An engine such as has just been described can be bought today, f.o.b. cars Bethlehem, for \$230,000, making the cost of the engine \$57.50 per kw.

Table I shows the installed cost per kw. of a gas engine power plant made up of three or more 4,000-kw. units as described above:

The only difference in this table from that shown in previous tables and published in the proceedings of the Association of Iron and Steel Electrical Engineers is in the cost of engine and related units, previous

tables being made up on the basis of 3,000-kw. units. The larger unit which served as a basis for this table occupies the same floor space as that covered by the previous tables and costs but very little more, the principal difference being in the diameter of the cylinders.

TABLE I

Showing installed cost per kw. capacity of a gas engine power station in 4,000-kw. units.

	Cost per kw.
Building, modern construction, brick and steel, tile floors, and crane, including exhaust tunnel and stacks.....	\$ 7.50 to \$ 15.00
Foundations for engines, including excavation at \$15.00 per cu. yd.....	4.50 to 9.00
Engines, including all piping painting ready to run	60.00 to 75.00
Gas cleaning apparatus.....	6.00 to 8.00
Generators, switchboard, exciters, oil switches for 6600 volts.....	13.00 to 20.00
Miscellaneous expenses	10.00 to 15.00
Total	\$101.00 to \$162.00
Average cost per kw.....	\$132.00

The subject of gas engines should not be passed without calling attention to at least one of the points for future improvements in net operating efficiency, namely, the utilization of the heat contained in the exhaust gases. Reclaiming this energy is somewhat similar to the application of condensers to the steam turbine. This field is merely scratched today in a few plants where feed water for boilers is heated in a small way. The water enters the piston rod at about 100 deg. F. and comes out at 130 deg. F., passes to the feed water heater, where it is raised to 170 deg. F. Much greater economies may be obtained by placing a large boiler or water heater so that the exhaust gases may pass through it on its way to the stack.

One very great possibility lies in the heating of water which may in turn be circulated in nearby buildings and used for heating purposes. In Germany steam boilers have been used, one showing 2.2 lbs. steam for each kwh. generated by the engine. Large boilers will, of course, produce more steam. It has been very conservatively estimated that the total efficiency of the gas engine may be increased easily 30 per cent by the use of exhaust gas boilers.

The reason such boilers have not come into more general use is that the efficiency of the gas engine is now high and the cost of coal not sufficiently high to urge the development of this line of apparatus.

Operation of Gas Engines.

Table II shows the operating cost of a gas engine power plant made up of six 3,000-kw. units and one 4,000-kw. unit.

In the matter of operating costs one of the principal items in the past has been the renewal of worn steel parts, such as pistons, cylinders, piston rods, etc. This item has been very materially reduced by the careful application of electric welding. Formerly when the grooves of the piston became worn to such an extent as to cause excessive leakage by the piston ring all that could be done was to remachine them and put in oversized rings. This, of course, could not be carried on indefinitely on account of

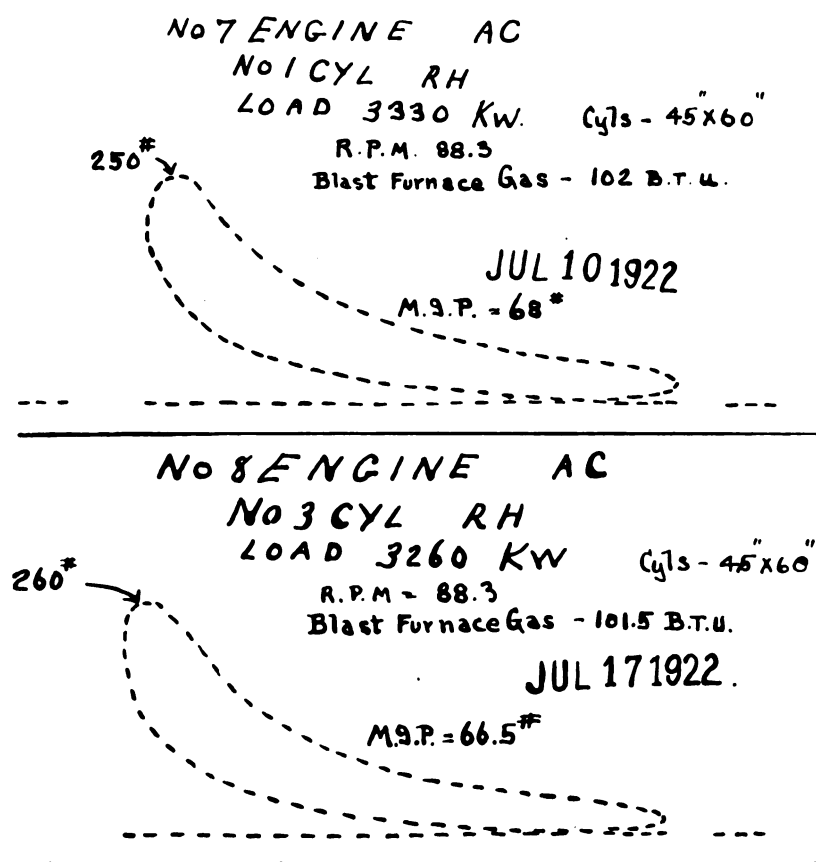


Fig. 1.

cutting away the metal. Today the worn places are filled up by electric welding and machined out so that the life of a steel piston is almost infinite. A cast iron piston cannot be thus welded.

TABLE II

	Cost per kwh.
Fuel—1,443,288,000 cu. ft. Average Btu. value 94 per cu. ft. at .0094 per 1,000 cu. ft.....	.00158
Labor—Including switchboard operators, engineers, oilers, superintendents, etc.....	.00030
Repairs—Including renewals, tools, miscellaneous supplies and labor in repairs.....	.00033
Water for cooling—Oil, waste and packing, including cooling pond expenses.....	.00021
Gas Cleaning—Including water, labor, repairs and power	.00037
Total operating cost.....	.00279
Heating feed water with exhaust gases (installed on 4 engines only) credit.....	.00033
Net operating cost.....	.00246

This table is practically the same as has been shown in previous discussions.

At times cracks develop in cylinder walls, especially in the vicinity of the exhaust ports, and formerly would necessitate the scrapping of the cylinder. Today these cracks are welded and seldom open up again; in fact, discarded cylinders have been reclaimed by this process to such an extent in one plant that four extra cylinders which were on order have been cancelled. It would seem, therefore, that with the proper application of electric welding a gas engine that is built of steel should never wear out and would be replaced only as a matter of obsolescence.

Diesel Oil Engine.

The Diesel oil engine which will be used as the basis of this discussion is a 2,700-kw., 8-cylinder, 2-cycle, single acting vertical engine operating at 115 rpm.

The cylinder is 26 in. in diameter and the engine is built in sections so that it can be supplied as 4, 6 or 8-cylinder engine and all of the like parts for each cylinder are interchangeable. The pistons are cast steel while the cylinder is cast iron. The Scavenger air inlet valve is in the center of the cylinder head, which has the inherent advantage of cleaning out absolutely all of the burnt gases with the exhaust so that the compression stroke has a full supply of fresh air to compress each revolution. With this construction the Scavenger air supplied is always somewhat greater in volume than the maximum capacity of the cylinder.

A 6-cylinder engine corresponding to this engine is now in operation in a boat carrying ore from Chile to Baltimore and New York. The fuel economy, ease of operation and absence of serious failures has considerably exceeded the expectations of the designers, and from all tests which have been carried out the indications are that this type of Diesel oil engine will not only have a very wide application in marine service, but will also make a place for itself in the generation of power. An 8-cylinder engine such as described above can be bought today, f.o.b. cars Bethlehem, for \$260,000.

The Operation of Diesel Oil Engines For Power Purposes.

While no costs are now available taken under actual perating conditions, tests which have been made bring

out very forcibly some of the possibilities in the Diesel oil engine.

Fuel economy tests on this engine show that under average conditions one kwh. can be produced with .630 of a lb. of 21 deg. Baume fuel oil which oil contains 19,100 Btu. pre lb. This is equal to .438 of a lb. per bhp. Since 2,545 Btu. equal 1 hph., the thermal efficiency at the crank shaft then is:

$$\frac{2,545 \times 100}{438 \times 1,910} = 30.42\%$$

Assuming generator efficiency as 93 per cent, the overall efficiency of such a power unit would be: $30.42 \times .93 = 28.47$ per cent, the overall efficiency at the switchboard.

In the matter of speed regulation an 8-cylinder, 2-cycle Diesel oil engine is superior to the twin tandem compound reciprocating steam engine which would have the same power impulses per revolution, and while we cannot expect it to be equal to that of the steam turbine, it is very close to it. In this connection it is interesting to note that for marine work no fly-wheel is used in connection with even a 6-cylinder engine and the engine is reversible. Of course, for power generation a flywheel would be used, although much lighter than is the case with a gas engine.

Comparison of Internal Combustion Engines With Steam Engines for Power Station Work.

One great weakness of any steam power station is its standby losses. By this is meant in plainest terms the coal that must be burned under the boilers to keep up steam pressure when all of the power generating apparatus is absolutely shut down. This coal amounts to a considerable item and if it were possible to avoid burning this coal, great savings could be effected in practically all power stations. This particular point has been very forcibly brought to the writer's attention in the matter of selling power over week-ends and holidays to the power company from whom we normally buy a small percentage of our power.

The operating superintendent of the power company states that it is real economy for him to buy power provided he did not have to bank his fires, but could burn them entirely out, as under certain conditions it requires almost as much coal to keep his fires banked over a light load period, such as Saturday afternoon, Saturday night, Sunday and Sunday nights, as would be burned if he were running a portion of his plant. Therefore, he has seen the wisdom of buying power which is generated in our gas engine power station over such periods. We all feel that each power engineer has a moral obligation to coming generations in the matter of conservation of our fuel reserve. Therefore, the power engineer is not only serving his best interests, but also the best interests of future generations in taking into consideration standby losses.

In previous papers on the subject of "Power Generation in Steel Plants," the writer has pointed out the economy of using gas engines for all loads between 100 per cent and 50 per cent load factor and the fact that steam turbines either located in a steel plant or in a central station should be used for absorbing the low load factor portion of the steel plant load. It is now evident that the third alternative should be added to the list for this character of service, namely, the Diesel oil engine.



Blast Furnace Waste Heat Utilized

Steel Plant May Be More Economically Operated if the Waste Heat and Waste Gases from the Blast Furnaces and Coke Ovens Are Completely Utilized.

By HUBERT HERMANN

UP to the end of the last century large gas-engines of 1,000 hp. were entirely unknown. In the year 1908 there were on the other hand more than 1,000,000 hp. of gas engines of over 1,000 hp. each in use all over the world. Of these there were:

		Pig-Iron Production
Germany	480,428 hp. or 46.5% at	11.8 mill. tons
U. S. A.	337,490 hp. or 32.5% at	16.2 mill. tons
France	55,050 hp. or 5.4% at	3.4 mill. tons
Belgium	46,714 hp. or 4.6% at	1.2 mill. tons
Austria	25,500 hp. or 2.4% at	1.4 mill. tons
Great Britain	24,986 hp. or 2.4% at	9.4 mill. tons
Other Countries	63,341 hp. or 6.2%	

These figures comprise engines driven by blast-furnace as well as coke-oven gas and generator gas. The possibilities of the utilization of gases from blast-furnaces and coke-ovens were thus only utilized to a small extent. However these conditions have improved very considerably, so that the utilization of the gases is now considered as important as the production of pig-iron. Unfortunately reliable figures for the present time are not available. It is, however, certain that all pig-iron and coke producing countries have diligently worked at the solution of the problem within the last decade. In the following a representation of the possibilities will be given which the utilization of the gases generated in blast-furnaces and coke-ovens offers at the present time, the utilization of the waste heat being specially considered.

Fig. 1 illustrates the energy balance sheet of a blast-furnace of 250 tons daily with a coke consumption of 10 tons per hour. Of the heat of 100 per cent introduced into the blast-furnace 40 per cent is consumed in the furnace itself, while 60 per cent leave the furnace as waste gases. The consumption of heat is distributed as shown in Table I:

TABLE I

	Loss %	Gain %
Evaporation of the water.....	3	
Reduction of the ores.....	20	
Radiation	4	
Heat contained in the slags.....	10	

Heat contained in the iron.....	3	
Waste gases	60	
	40	60
		100

The recovered 60 per cent of waste gases are distributed as follows:

Heating of the air blast.....	28
Of this heat developed in the furnace...	14
Loss	14
Power required by the furnace.....	9
Of this current for the furnace.....	3.5
For the blowers.....	5.5
Excess of gases.....	23
	60

Fig. 2 illustrates the energy balance sheet of a regenerative coke-oven with a generator for gasifying the coke dross. The balance sheet is based upon a battery of coke ovens for 200 tons daily output of coke, corresponding with a charge of 240 tons coal. Owing to the heating of the coke-oven the contents of heat is at first increased by 3 per cent, which however, is lost again later on by the cooling of the coke and the gases. The 100 per cent of heat introduced into the oven with the coal is distributed according to the following Table II:

TABLE II

	Loss %	Gain %
Coke output of the oven.....	75-83	
Gasification and combustion.....	5- 3	
Waste gases		22-14
	80-86	22-14
Distribution of the heat of the gases:		
Chemically combined with tar and benzole	1- 5	
Heating of the coke ovens.....	7-10	
Gases which can be utilized		6- 7
	8-15	6- 7



a question of local conditions whether the coke-oven gas is utilized as fuel for heating furnaces or for driving gas engines. If there is a sufficient demand for the energy generated the use of gas engines in conjunction with coke-ovens can be recommended, be-



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cause by the driving of such machinery the highest amount of energy can be withdrawn from the waste gases.

In the coke-oven industry the conditions for the employment of large gas engines are, therefore, not as favorable as in the blast-furnace industry, but the excess gases recovered more than suffice for their own requirements of the coal mines. The older construc-

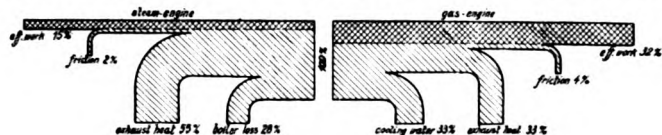


Fig. 3.

tions of coke flame ovens supplied their excess energy in the form of waste heat, which could only be employed for heating steam boilers. Ovens with by-product recovery installations without regenerative furnaces supply waste heat and waste gases. If the waste gases are burned in gas-engines instead of in boilers, the total engine output obtainable from the coke-oven is increased by about one-third. Regenerative ovens supply energy only in the form of coke-oven gas which in gas-engines produces double the amount of work as in steam boilers. The regenerative working of coke-ovens gives on the whole no higher quantity of energy than ovens with by-product recovery without regenerative furnace, which utilize their waste heat in steam plants and their waste gas in gas-engines, but their advantage is in the uniform kind of engine which can be employed and the simpler working conditions.

The internal combustion engine is far superior as regards conversion of heat into work to the steam plant. The gas engine has a heat efficiency up to 35 per cent, while the best steam plant hardly ever reaches 17 per cent.

In Fig. 3 the heat balance sheets of the steam engine and the gas engine are shown side by side.

Of 100 per cent heat introduced are consumed:

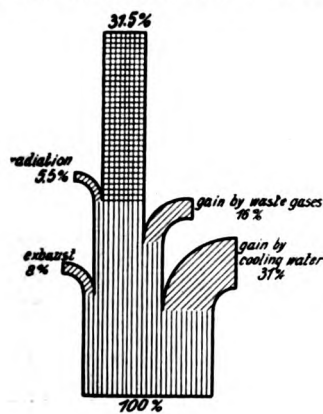


Fig. 4.

As this Table III shows in the gas-engine also large quantities of heat are lost in the exhaust gases and the cooling water. By employing waste heat utilizers in conjunction with the engines a large part of the waste heat may be recovered. In Germany very extensive experiences have been gained in this respect, as there the economical conditions peremptorily demand the most perfect utilization of the energy. Even in the year 1903 a gas-engine plant of more than 10,000 hp.

TABLE III

	Steam-engine %	Gas-engine %
Loss in boilers.....	28	..
Waste heat	55	..
Friction losses	2	5
Cooling water	..	33
Exhaust heat	..	30
Effective work	15	32
	100	100

was furnished with waste heat boiler for the generation of steam. However it is only since 1910 waste heat utilizers have been employed to a large extent.

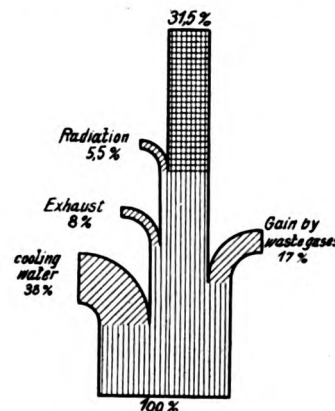


Fig. 5.

The waste heat from gas-engines and internal combustion engines may be utilized in various ways:

1. The cooling water which has become warm can be used for industrial purposes, in both installations, etc.
2. The warm cooling water can be further heated by waste gases and then be utilized for heating installations, boiler feed and the like.
3. Fresh water can be heated by waste gases.
4. Air may be heated by waste gases for drying

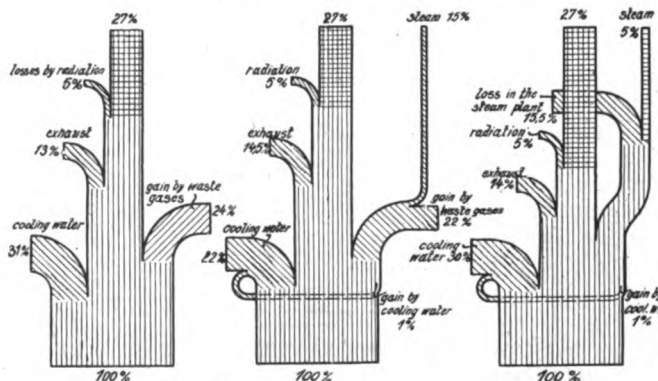


Fig. 6.

Fig. 7.

Fig. 8.

purposes or drying chambers may be directly heated by the waste gases.

5. Water may be distilled by the waste gases.
6. Steam may be raised by the waste gases.

The gain produced by the recovery of waste heat fluctuates according to the possibilities of the utilization of the waste heat and the local conditions.

Figs. 4 and 5 show the fuel-utilization of a double-

acting horizontal Diesel engine with a plant for the utilization of the cooling water and the exhaust gases: Fig. 4 in conjunction with the preparation of hot water in a closed circuit and Fig. 5 in conjunction with the raising of steam and the preparation of distilled water. The highest possible extent of the utilization (Fig. 4) which occurs in work, with a high demand for hot water (breweries, dye-works) amounts to about 84 per cent of the heat put into the engine. Individually the balance sheet figures in Figs. 4 and 5 correspond with the figures in Table IV.

TABLE IV

	Fig. 4.		Fig. 5.	
	Loss %	Gain %	Loss %	Gain %
Exhaust losses	8		8	
Radiation losses	5.5		5.5	
Cooling water losses			38	
Gain by waste gases		16		17
Gain by cooling water		39		..
Gain by engine efficiency		31.5		31.5
	13.5	86.5	51.5	48.5
	100		100	

Figs. 6, 7 and 8 show the conditions in a gas engine of 2,000 hp. with plant for preparing hot water for boiler supply, heating and so on (Fig. 6), in conjunction

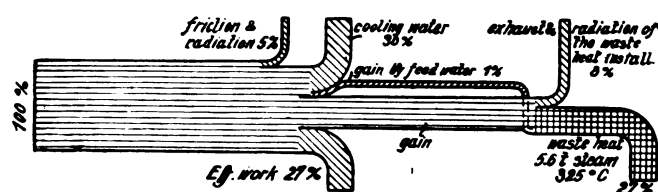


Fig. 9.

with the generation of high pressure steam for power purposes and utilization of the waste steam for chemical purposes (Fig. 7), and for the generation of power only. In Table 5 the balance sheet values are tabulated.

TABLE V

	Loss %	Gain %	Loss %	Gain %	Loss %	Gain %
Radiation	5		5		5	
Exhaust	13		14.5		14.5	
Cooling water	31		30		30	
Steam-raising plant		24.7		..		..
Waste gases		..		..		..
Waste steam		..	22	..		..
Working steam		..	1.5	..	5	..
Engine efficiency		27	27	27	27	27
	49	51	49.5	50.5	50.5	32

Fig. 9 shows the heat balance sheet of a blast-furnace installation of 6,000 hp. with waste heat utilization, in which 5 or 6 tons of steam at 12 atm. and 325 deg. C. are generated. The output of about 0.93 kgs. steam per gas hp. per hour resulting according to Fig. 9 is obtained in gas-engines of medium sizes at full load, that means at the most favorable heat efficiency value of the engine.

At lower loads and less careful supervision the engine requires larger quantities of heat, which is mainly carried away by the exhaust gases and is recovered for the larger part by the waste heat utilization plant.

Table VI gives a balance sheet of this installation.

TABLE VI

	Loss %	Gain %
Friction and radiation	5	
Cooling water	30	
Exhaust and radiation in the waste heat installation	9	
Waste heat		29
Mechanical work		27
	44	56
	100	

PENN SEABOARD STEEL TO INCREASE ITS STOCK

A special meeting of stockholders of the Penn Seaboard Steel Corporation, Philadelphia, will be held September 29, for a vote on an increase in capital from 700,000 shares to 1,200,000 shares of stock of no par value. This is the same increase as proposed a few months ago when negotiations were under way looking toward the acquisition of the Carpenter Steel Company, Reading, Pa., although it is said these merger plans now have been abandoned. President J. B. Warren, of the Penn Seaboard Company, in a letter to stockholders declares the increase in capitalization is desired to enable the corporation to acquire further properties; to reduce materially or retire completely the corporation's funded debt; and to obtain additional working capital in order to properly handle increased business now on hand and in prospect. Penn Seaboard's capital was increased last November from 350,000 shares to 700,000 shares when the Titusville Forge property at Titusville, Pa., was acquired.

TO DISMANTLE BAR MILL

Dismantling of the bar mill of the Carnegie Steel Company at Greenville, Pa., has been ordered and work of demolition will start at once. The Greenville plant has not been in use for the past four years and has a rated capacity of 96,000 tons of bars and small shapes. Operations were discontinued when the new mills of the company were started at McDonald, O. Most of the Greenville employees moved to McDonald. Officials of the company recently inspected the plant and the order to dismantle followed. This is the second plant of the Carnegie Steel Company in the Western Pennsylvania district which is being scrapped. The North Works at Sharon, Pa., is being dismantled at the present time.

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

The Blast Furnace Steel Plant

[Required by Act of Congress of August 21, 1912]

Name of Publication: **The Blast Furnace and Steel Plant**, published monthly at Pittsburgh, Pa. [Report for October 1, 1922.]

Publisher—The Andresen Co., Inc., 108 Smithfield St., Pittsburgh, Pa.

Editor—D. N. Watkins, 108 Smithfield St., Pittsburgh, Pa.

Managing Editor—F. C. Andresen, 108 Smithfield St., Pittsburgh, Pa.

Business Manager—F. C. Andresen, 108 Smithfield St., Pittsburgh, Pa.

(Names and addresses of stockholders holding 1 per cent or more of total amount of stock:

Estate of H. A. Andresen, care Colonial Trust Co., Pittsburgh, Pa.

F. C. Andresen, 108 Smithfield St., Pittsburgh, Pa.

L. L. Carson, 108 Smithfield St., Pittsburgh, Pa.

R. H. Thiess, 108 Smithfield St., Pittsburgh, Pa.

M. M. Zeder, 108 Smithfield St., Pittsburgh, Pa.

Known bondholders, mortgagees, and other security holders holding 1 per cent or more of total amount of bonds, mortgages, or other securities: None.

F. C. ANDRESEN, Business Manager.

Sworn to and subscribed before me this 20th day of September, 1922.

JOHN N. ENGLISH, Notary Public.

(My commission expires March 9, 1923.)

NEWS OF THE PLANTS

The Pacific Steel Corporation, San Francisco, Cal., recently organized under Delaware laws with a capital of \$20,000,000, will comprise a consolidation of the Pacific Coast Steel Company and the Southern California Iron & Steel Company, as well as other iron and steel concerns now operating on the Pacific Coast, and whose names will be announced at a later date. The new company will also take over the iron ore properties of the Milner Corporation in Utah. The first noted company, the Pacific Coast Steel Company, operates plants at San Francisco and Portland, while the Southern California Company has its works at Los Angeles. Plans are now being perfected for extensive additions and improvements in these works, including the installation of additional equipment for increased output. A large new plant for the production of pig iron will be established on a site to be selected in Utah; this works will comprise blast furnace, mills, power plant, etc., and is estimated to cost in excess of \$5,000,000. The new corporation is represented by T. T. C. Gregory, Insurance Exchange Building, San Francisco.

The Meadville Malleable Iron Company, Mill Street, Meadville, Pa., has taken bids for the erection of a new brick and steel addition to its plant, to comprise a one-story building, equipped as an annealing works. It is planned to commence the construction at an early date. Shutts & Morrison, Marine Bank Building, Erie, Pa., are architects in charge.

The Wickwire-Spencer Steel Corporation, Worcester, Mass., has arranged for a note issue of \$1,775,000, the proceeds to be used for proposed extensions and general expansion, as well as financing in connection with the acquisition of the plant and business of the American Wire Fabrics Company, with mills at Mt. Wolf, Pa., and Blue Island, Ill. The corporation is also operating other plants at Worcester, Spencer, Palmer, and Clinton, Mass., as well as at Buffalo, N. Y. Plans are being arranged for the immediate rebuilding of the portion of the mill at Spencer, recently destroyed by fire with a loss estimated at close to \$40,000, including equipment. The new mill section is estimated to cost approximately a like amount; it will be three-story, 33x100 ft.

The Bethlehem Steel Corporation, Bethlehem, Pa., has commenced preliminary work for the proposed expansion of its plant at Sparrows Point, Baltimore, Md., for which a fund of \$3,500,000 recently was authorized. The work will include an addition to the present No. 2 open hearth furnace, comprising a 250-ton tilting furnace unit, to make a complete operating unit of five 250-ton open hearth furnaces. The present five stationary furnaces, each of 70-ton capacity, will be augmented with four new 100-ton units, bringing about an increased ingot production of about 400,000 tons a year, total. A new power plant will be constructed at the mill, with initial installation of a 10,000-kw. turbo-generating unit, with new boiler plant, steam condensing department, etc., to be operated as an auxiliary to the present gas engine station.

The Crucible Steel Castings Company, Canal Road, Cleveland, Ohio, will commence the immediate erection of a new plant at Almira Avenue and East Eighty-second Street. It will be one-story, 100x240 ft., and is estimated to cost close to \$100,000, including machinery. The general building contract has been awarded to the Samuel W. Emerson Company, Euclid Building, Cleveland. G. S. Rider & Company, Century Building, Cleveland, are architects and engineers.

The Ohio Steel Products Company, Mineral Ridge, Ohio, is perfecting plans for the sale of its local plant, which has been inactive for some time past. The company has been operating with a capital of \$500,000, engaging in a general line of steel production. It is said that negotiations are under way for the purchase of the property, and that the prospective new owners plan to place the works in service at an early date.

The Rich Steel Products Company, Battle Creek, Mich., has preliminary plans in progress for the erection of a new plant, on local site, to be equipped for the production of a general line of steel products. The new plant will be one and two-story, and is estimated to cost in excess of \$350,000, including machinery. It is expected to perfect the details of the new mills by the close of the year and to break ground for the structures early in 1923. The company is now operating a plant on Springfield Place, Battle Creek, and it is said will remove this works to the new location following the completion.

The Standard Seamless Tube Company, 313 Sixth Avenue, Pittsburgh, Pa., has preliminary plans in progress for the construction of an addition to its plant at Ambridge, Pa., for increased production. The structure will be one-story, 80x500 ft.

The Belle City Malleable Iron Company, Kewaunee Street, Racine, Wis., has completed plans and will commence the immediate construction of a new plant on local site for the manufacture of a general line of iron products. The works will be one and two-story, 80x100 ft., and are estimated to cost about \$75,000. A list of equipment to be installed will be prepared at an early date. The company will establish headquarters at this location and will build an office building for this purpose.

The Morristown Electric Steel Company, Inc., 13 Water Street, Morristown, N. J., recently organized, has acquired the former plant of the Liberty Steel Company in the Shelley Terminal District, and will take immediate possession for its proposed works. The present structure will be remodeled and improved, it is stated, and considerable new equipment installed for electric steel production. The new company is headed by Samuel B. Illingsworth and J. Lovel Paulmier, both of Newark, N. J., and Richard A. Eurich, Morristown.

The Electrolytic Iron Company, Bridgeport, Conn., recently organized, has acquired the plant at Milford, Conn., formerly occupied by the Page & Nettleton Company, situated on New Haven Avenue. The new owners plan for the immediate establishment of a new works for the production of pure iron by the electrolysis process, and complete equipment for this purpose will be installed. The present factory building will be remodeled and improved to accommodate the new industry. The works will include an extensive testing laboratory.

The Damascus Crucible Steel Castings Company, New Brighton, Pa., has acquired a tract of property at Hammond, Ind., fronting on the Nickel Plate railroad lines, totaling about 10 acres of land. The tract will be used for the erection of a new plant, for which plans will be placed in progress at an early date. It is expected to equip the initial buildings to give employment to a working force of about 300 men. Bids will be asked for construction, it is said, at an early date, and a list of machinery to be installed will be arranged. The estimated cost of the project has not, as yet, been announced.

WITH THE EQUIPMENT MANUFACTURERS

NEW BLEEDER TYPE TURBINE

Increasing competition demands lower manufacturing and operating costs and better steam economy in every industrial plant. Heretofore, as would be most natural, especial study has centralized upon the large power installations and the smaller plant has not made the same progress toward economical operation that has been perfected in the plant many times larger.

In line, however, with a desire to decrease operating costs in the average size industrial power plant, the Moore Bleeder Type Turbine has been thoroughly perfected and placed upon the market. It fulfills a long felt want wherever steam, after generating power, is used for heating buildings, heating feed water for boilers, manufacturing and cooking. It solves in a satisfactory manner the problem of heat balance and acts as a reducing valve for converting high pressure steam to a lower desired pressure, meanwhile extracting the energy due to the heat drop.

It is simple in design, easy to "get at" and automatically regulates perfectly, either for varying power conditions or fluctuating demands for exhaust steam.

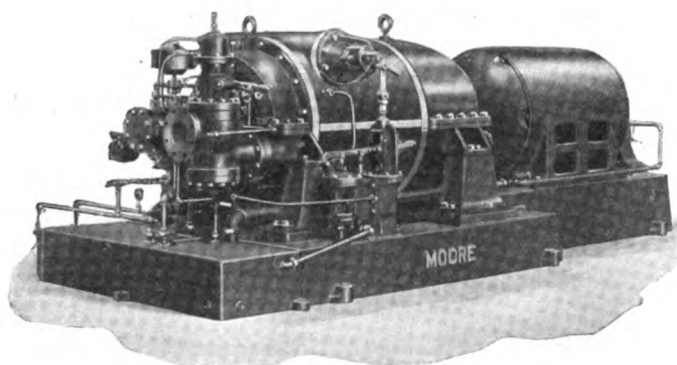


FIG. 1. BLEEDER TURBINE FROM BLEEDER VALVE SIDE

The efficiencies obtained have proven exceedingly gratifying. One operator, for instance, who had bought outside power at \$600 per month, yet who had generated steam in his boilers at 125 lbs. per sq. in. and reduced it to 40 lbs. per sq. in. through a reducing valve, for cooking purposes, found that a Moore Bleeder Turbine could take the place of the reducing valve, generate his power requirements and fulfill his demand for exhaust steam. He saved \$600 per month, which in less than a year paid for the turbo-generator. There are doubtless many operators today who could follow the same procedure with resulting greater efficiencies and lower operating costs.

The general design of the Moore Bleeder Type is that of a multistage turbine, with one or two velocity stages followed by a number of pressure stages. Between the velocity stage and pressure stage is the bleeder chamber "A," Fig. 2, which connects to the heating or cooking system. The cylindrical bleeder valve allows excess steam to enter chamber "B," from which point it flows through the pressure wheels to the condenser.

An oil relay governor controls the turbine speed. A cylindrical bleeder valve controls the steam flow rate to the bleeder exhaust.

Since the bleeder type serves as a combination non-condensing high pressure condensing turbine, it effects a close heat balance, even where there are only one or two main units. The flow of steam to a heating system being determined by the pressure of that system, the load to be carried by the high and low pressure elements, in order to result in the proper heat balance, is automatically determined by the cylindrical bleeder valve which regulates the flow of low pressure steam to the heating system. The oil relay governor automatically regulates the flow of high pressure steam to the high pressure stages to meet changing load conditions. Hence with these two simple and positive equalizers a perfect balance is automatically maintained.

Among the claims for the Moore Bleeder Turbine, with its cylindrical valve, may be mentioned the following:

The cylindrical type of valve gives a wide, unobstructed opening with minimum pressure drop from "A" to "B." (A

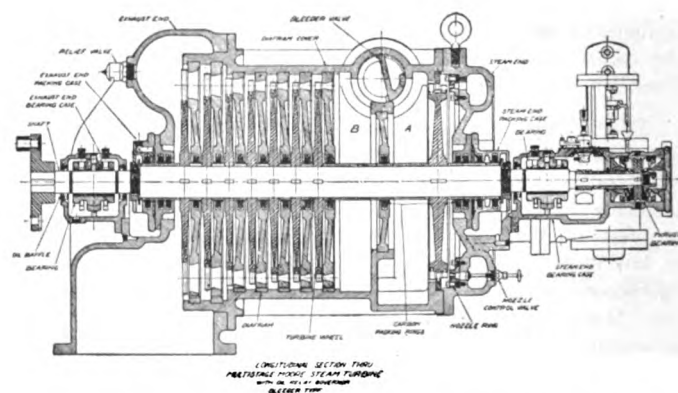


FIG. 2. CROSS SECTION OF MOORE BLEEDER TURBINE

drop between these two points means loss in efficiency.)

The weight of the valve, together with the thrust due to steam pressure, is carried on two large bearings, one at either end. Very little effort is required to turn the valve.

The bleeder valve clearance is greater than the end bearing clearances. This not only makes for easy rotation of the valve, but likewise allows a small quantity of high pressure steam to leak past the valve into the low pressure stage. This prevents high temperatures which occur due to windage friction of the rotating elements in the surrounding thinned out steam.

The entire bleeder valve can be quickly removed without disturbing or dismantling the casing.

The valve forms part of the turbine casing, thereby presenting a compact appearance.

The valve arrangement has only a few parts and requires little attention.

The Moore bleeder turbine is built for initial pressures as low as 100 lbs. per sq. in. and bleeder pressure as high as 40 lbs. per sq. in.



Harry W. Irwin recently resigned his position as superintendent, which occupation he has held for several years, at the plant of the Canton Sheet Steel Company, Canton, Ohio, to become superintendent of the Universal Steel Company, Bridgeville, Pa. Mr. Irwin went to Canton in 1901 and became identified with the Stark Rolling Mill Company.

✓ ✓

John Leyshon, who resigned recently his connections with the Gary, Ind., plant of the American Sheet & Tin Plate Company, to become general manager of the India Tin Plate Company, Galmuri, India, was scheduled to sail during the week of September 1 for London, thence via Suez canal for India. Mr. Leyshon formerly was employed at the Farrell, Pa., works of the American company. D. W. Samson is to be hot mill superintendent at Gary.

✓ ✓

A. W. Ambrose will become assistant director of the bureau of mines, October 1, succeeding E. A. Holbrook, who has become dean of the mining school of Pennsylvania State College. Mr. Ambrose is now chief petroleum technologist of the bureau. He is a graduate of Stanford University and has been with the bureau since 1917. F. J. Bailey, assistant to H. Foster Bain, director, and a graduate of Middlebury College, Vt., will handle all of the business matters of the bureau formerly under the assistant director, thus permitting Mr. Ambrose to supervise the petroleum activities of the bureau in a general way.

✓ ✓

J. Brynmor Hill, director Gorsienon Steel & Tinplate Works, Swansea, Wales, who recently spent several weeks in this country in visiting steel plants, was a passenger on the Majestic, which sailed from New York, August 26.

✓ ✓

A. G. Douglas, chief engineer, and W. H. Mortlock, production manager, Hoskins Iron & Steel Company, Ltd., Lithgow, New South Wales, Australia, recently visited the plant of the St. Louis Coke & Chemical Company, Granite City, Illinois. These gentlemen are visiting a number of representative iron and steel plants in this country and Canada for the purpose of familiarizing themselves with American practice.

✓ ✓

H. H. Harris, formerly with the Union plant of the Bethlehem Shipbuilding Corporation, has been appointed assistant

manager and chief engineer of the Hanlon Drydock & Shipbuilding Company, Oakland, Cal.

✓ ✓

Walter Rachals, assistant to chief engineer of the United States Steel Corporation, returned September 14, following a visit of several months in England, France, Belgium and Germany.

✓ ✓

F. M. Mitchell, assistant general manager of the Broken Hill Proprietary Company, Ltd., steel works, New South Wales, Australia, recently arrived in this country and is visiting steel plants in the Pittsburgh, Chicago and other producing centers. Mr. Mitchell expects to leave San Francisco for Australia on November 10.

✓ ✓

John W. Porter, vice-president of the Alabama Company, who has been resting from his duties for several weeks, has returned to Birmingham and is again at his desk fully restored to normal health.

✓ ✓

D. J. Felkel recently resigned as superintendent of the Covington, Va., blast furnace plant of the Low Moor Iron Company to become connected with the blast furnace department of the Cia. Fundidora de Fierro y Acero de Monterrey, S. A., Monterrey, N. L., Mexico, in the same capacity.

✓ ✓

George B. Waterhouse, metallurgist of the Lackawanna Steel Company, has been secured by the Massachusetts Institute of Technology, Boston, to take charge of the metallurgical lines. Dr. Waterhouse has resigned his connection with the Lackawanna company, and will take up his new duties with the opening of the fall term at the Institute. He has been with the Lackawanna company for 16 years.

✓ ✓

John J. Whiting has resigned his position as assistant manager of the Mayville Plant of the Steel & Tube Company of America to accept the position of superintendent of blast furnaces of the Donner Steel Company, Buffalo, N. Y., and Tonawanda, N. Y.

✓ ✓

W. S. Rugg, assistant to vice-president, Westinghouse Electric & Manufacturing Company, has been appointed to the newly created position of general manager of sales of that company.



J. Fred Townsend, traffic manager of the National Tube Company, Pittsburgh, has been elected vice-president of the Lake Terminal Railroad, the McKeesport Connecting Railroad and the Benwood & Wheeling Connecting Railway, subsidiaries of the National Tube Company.

✓ ✓

Gustavus Pratt has been in the employ of the Stanley Works, New Britain, Conn., for 60 years. Mr. Pratt's father was employed in the same company for 65 years, the combined service being 125 years. In these times of unusual labor turnover, this record of long and efficient service is noteworthy.

✓ ✓

John Goodin Carruthers, for more than three years district manager of sales for the Illinois Steel Company, at Chicago, leaves that position October 1 to become general manager of sales for the Otis Steel Company, at Cleveland. He will be succeeded by David Buffington, who has been in the general sales department of the former company for many years.

✓ ✓

Owen K. Parmiter, metallurgist, Firth Sterling Steel Company, McKeesport, Pa., was the speaker at the monthly meeting of Pittsburgh Chapter, American Society for Steel Treating at the William Penn Hotel, Pittsburgh, Tuesday evening, September 5. His subject was "Stainless Steels."

✓ ✓

Col. C. H. Crawford, South American manager of the Baldwin Locomotive Works, and Clifford Shoemaker, Washington, have been appointed representatives of the American Association of Engineers at the International Engineering Congress held this month at Rio de Janeiro. The purpose of the conference is to establish closer contact among those engaged on problems of economic progress in all the Americas.

✓ ✓

Frank B. Worriow recently resigned as superintendent of the Millbury Steel Foundry Company, Millbury, Mass., which position he has held for the past five years, to become associated in the same capacity for a foundry in Pittsburgh.

✓ ✓

A. D. Neal, recently connected with the roll department of the Duquesne Steel Foundry Company, Pittsburgh, and formerly identified with the sales department of the Carnegie

Steel Company, Homestead, Pa., has been added to the sales force of the Pittsburgh Rolls Corporation, Pittsburgh.

✓ ✓

The United Alloy Steel Corporation, Canton, Ohio, recently made a number of changes in their organization. H. C. Thomas was promoted from general superintendent to assistant general manager; J. B. Thorpe was appointed general superintendent of the Alloy Division, and H. T. McBratney, general superintendent of the Sheet Division. Mr. Thomas and Mr. Thorpe were formerly connected with the Gary Steel Works of the U. S. Steel Corporation, the former as assistant general superintendent and the latter as open hearth superintendent, both going to the United Alloy Corporation in 1918. Mr. McBratney was for a number of years general superintendent of the sheet mills of the Allegheny Steel Company, Breckenridge, Pa.

✓ ✓

B. D. Quarrie, vice-president and general manager of the Otis Steel Company, Cleveland, has been elected director of the Guardian Savings & Trust Company, that city.

✓ ✓

W. H. Ryan, for many years associated with Pratt & Letchworth Company, Buffalo, has accepted the position of superintendent of the Malleable Department of the Superior Steel Castings Company, Benton Harbor, Mich.

✓ ✓

J. C. Peil, formerly superintendent of foundries, Maxwell Motor Company, Dayton, Ohio, later in a like position with the Rumley Company, La Porte, Ind., has taken an interest in the Ypsilanti Motor Castings Company, Ypsilanti, Mich., and has become superintendent of that company.

✓ ✓

Robert C. Yates, for many years identified with the Union Drop Forge Company, Chicago, has resigned to become associated in the capacity of general manager of the Interstate Drop Forge Company, Milwaukee, Wis. Mr. Yates, after graduating from Union College, was connected with the American Locomotive Company, at Schenectady, N. Y., and Bethlehem Steel Company, having also been manager for a time of the Chicago district office of Bethlehem. The Interstate Drop Forge Company, which was organized in 1919 for the manufacture of small commercial forgings, is closely allied with the Chain Belt Company, Sivyer Steel Casting Company, and Federal Malleable Company, all of Milwaukee.

Some Pointers on By-Product Coke Oven Operations

COKING PROPENSITIES OF COAL

The results of investigations, carried out during the last five years in the fuel laboratories of the Imperial College of Science and Technology, into the resinic constituents of bituminous coals and their supposedly determining influence upon coking propensities, indicate that strongly-coking bituminous coals may be extracted for prolonged periods by organic resin-solvents without impairing their coking propensities.

The pyridine-chloroform method of extracting coals yields an admixture of resins with a predominance of non-resinous substances, chiefly of cellulosic origin. The resins may be extracted and isolated in a pure condition from such coals by the pyridine-amyl alcohol treatment, with successive treatments with ethyl ether and light petroleum. These resins, however, do not generally exceed 1 per cent of the coal substance and are not a chief cause of the coking propensities of coals.

A series of non-resinous substances, mostly insoluble in ether, but soluble in chloroform, are also obtainable by the above mentioned treatments. They amount to as much as 4 per cent with strong coking coals. These non-resinous substances, upon being heated out of contact with air, give a strong exothermic reaction between 275 deg. and 375 deg. C., accompanied by the elimination of water. This shows them to be cellulosic in type and origin.

It is shown that the coking propensities of coals are principally due to the presence of such non-resinous substances of cellulosic origin, whose fusion temperatures are below those at which they undergo rapid decomposition; furthermore, the more complex substances, also of cellulosic origin, which form the main portion of the coal substance, but which decompose without fusion, have little or no direct influence upon its coking propensities.

LOW TEMPERATURE CARBONIZATION OF COAL

While referring to the aims and advantageous results anticipated from low temperature carbonization of coal, the author comments upon its success from an economical point of view. Hitherto, it has been far from a paying proposition.

Difficulties in the past have been threefold, viz., the swelling of the charge, the long period of carbonization required, and the unmarketable quality of the fuel, due to its friability. A knowledge of the chemical constitution of coal would appear to be the keystone of the problem, and investigations have been made by the author in this respect.

He discusses the properties of the four main types of substance of which coal consists—the alpha, gamma, beta, and ulmin compounds—and a sketch gives a classification of the various types of coal, conditioned by the amounts of the four ingredients in question, and by the relative amounts of the various types of beta and gamma compounds. Here is shown in a qualitative manner the variation in composition of the various types of coal, with quantitative results.

The divers stages of coke structure are described. Temperature gradient and plasticity of the coal mass are important points for consideration, and the author demonstrates that one-stage coals are practically responsible for fairly good, low temperature coke. It is the natural one-stage coal, where the gamma compound is decomposed between a short interval of temperature, which can be carbonized at low temperatures with some degree of success.

"CHANCE" PROCESS OF FLOTATION

A new flotation process, which bids fair to modify greatly the methods now employed in the preparation of anthracite, has been designed by Mr. T. M. Chance, of H. M. Chance & Company, Philadelphia.

The machine utilizes a mixture of fine sea sand and water. The maximum specific gravity obtainable with these substances will closely approximate that of the sand itself, while it may vary from this down to unity, or the specific gravity of the water used.

Illustrations show plans designed for a new type of preparation plant, utilizing the new kind of separation machine, destined for a building 129 ft. in height. The operation of a double preparator, with a capacity of 2,000 tons of coal per day, the feed being 3,300 tons (40 per cent of which is refuse), requires 41 men. The cubical contents of the structure will be 670,000 cu. ft., and the volume per ton of daily capacity will be 335 cu. ft. Preliminary estimates show that a building of this type and size would require 475 tons of structural steel.

The mode of operation is minutely described, from which it would appear that the division of the coal from the slate or bone is done before the coal is sized. When the coal flows over from a cone, it is screened into egg, stove, nut, pea, buckwheat and birdseye, and the fine sand it removed. The refuse falls to the bottom of the cone, is trapped in a chamber having an upper and lower gate, provided with an interlocking device, preventing the two being opened at the same time, and is transported to a chute by a refuse conveyor.

SILICA BRICK FOR COKE OVENS

The British practice of using quartzite brick was referred to in a recent paper read before the Coke Oven Managers' Association. The author urges the necessity for seriously considering, in the case of erection of new ovens, whether silica brick should not be used instead of the present generally utilized quartzite. The advantages show that with the former quality of brick, higher temperatures, greater output, and greater thermal efficiency are obtainable. At high temperatures, its conductivity is considerably superior, and instances are quoted, where the future general use of silica brick is predicted.

It is suggested that there is no sacrifice of by-product yield, and as regards durability, most favorable results are shown by ovens built of silica brick. Corrosion of the walls, which frequently happens where salty coal is used, would be avoided by the employment of silica, and no clearer or more convincing evidence could be cited in the latter's favor than where two batteries of coke ovens, respectively built of silica and quartzite, were working side by side. The former lasted six years, while the latter required rebuilding after three to nine months.

A matter of importance is the property which silica brick possesses of expanding permanently, and when working at high temperatures care should be taken to select a brick of which the permanent expansion is low.

Reference is made to the crystal modifications of silica, which, on account of the accompanying tremendous changes in volume, should take place in the kiln, and not in the oven. A table shows the changes which take place when silica brick is heated.

Ganister or quartzite, suitable for a first class brick, should not contain less than 97 per cent silica, and an ideal composition is mentioned. Physical properties are equally as important, and it is not advisable to use a brick with a higher specific gravity than 2.35.

TRADE NOTES

The Consolidated Gas Electric Light & Power Company of Baltimore has placed order with The U. G. I. Contracting Company of Philadelphia for two U. G. I. tar extractors, each having a capacity of 6,000,000 cu. ft. per day. The latter company has also received orders to install two similar tar extractors at the Langsdale Avenue plant of the Citizens Gas Company of Indianapolis, and one tar extractor of 4,500,000 cu. ft. capacity at its Prospect Street plant.

F. J. Ryan & Company, Wesley Building, Philadelphia, Pa., industrial furnace equipment specialists, announce the recent receipt of contracts for furnace equipments from the following concerns: American Fork & Hoe Company, Milton Manufacturing Company, Crucible Steel Castings Company, Cleveland, Ohio; Davis Brothers, New Process Metals Corporation.

The Power Specialty Company, 111 Broadway, New York, announces the appointment of Pell W. Foster, Jr., as New England district manager, with offices at 50 Congress Street, Boston. Mr. Foster was formerly in the New York sales office.

The Chicago Flexible Shaft Company, Roosevelt Road and Central Avenue, Chicago, has opened a new district sales office, with headquarters at 305 Merchants Bank Building, Indianapolis, to handle furnace sales in Southern Ohio and Indiana, and Western West Virginia. F. W. Odemar is in charge.

Alfred Box & Company, Inc., Philadelphia, electric and hand cranes and hoists, opened a factory branch office at 30 Church Street, New York, on September 15. N. C. Failer, an engineer who has specialized in handling these lines, is in charge. This is the beginning of a plan to establish direct factory branches in a number of large business centers.

The Economy Fuse & Mfg. Company, Greenview Avenue, Chicago, has moved its Detroit sales office from 1012 Majestic Building to 1528 First National Bank Building.

The Diamond Chain & Mfg. Company, Indianapolis, announces the opening of an office at 340 Leader-News Building, Cleveland. H. I. Markey, for five years mechanical engineer with the Diamond Chain Company, will be in charge.

The United States Coal & Coke Company, Gary, W. Va., are going to use bone coal, which was formerly considered waste, as a boiler fuel. To this end they are installing in their new plant two 46-in. Fuller-Lehigh screen mills for pulverizing coal,

Fuller-Kinyon distributing system for conveying the pulverized coal from the mills to the furnace bins and each 800-hp. boiler will be equipped with five vertical burners, taking the fuel from five 3-in. screw feeders.

TRADE PUBLICATIONS

The Bristol Company, Waterbury, Conn., have issued a new 68-page catalogue devoted to Bristol pyrometers. The catalogue is very profusely illustrated and contains very valuable condensed information on the subject. The catalogue is No. 1401 Bristol's Pyrometers.

F. J. Ryan & Company have recently issued Bulletin 4A, entitled, "Liquid Fuel Burning for the Generation of Steam." It is very interesting and will be sent upon request.

The Brown Instrument Company have issued a new Catalogue No. 85 on the automatic control of temperatures through Brown indicating and recording instruments.

One of the most interesting publications of the year in the mechanical stoker field is the new bulletin, "Cutting the Cost of Producing Steam," just published by the Detroit Stoker Company of Detroit, Mich. The bulletin starts with the premise that "One of the conditions necessary to the efficient combustion of coal is the uniform liberation of the volatile gases. This is a condition which practically never can be obtained in the hand-fired furnace. Inasmuch as the hand-fired furnace also represents definite limitations in the way of utilizing the cheapest grades of fuel, engineers are today finding that the way to improve boiler room operating conditions is to install mechanical stokers." From this point the bulletin takes up the dollars and cents value of mechanical stokers, dealing with each of the savings effected, in detail. It next deals with the application of advanced engineering principles and modern stoker design, and then concludes with a section on the service of the mechanical stoker, unique in its treatment. The bulletin is a beautiful example of the printer's and engraver's art, as well as being one of the most readable and interesting pieces of literature put out in the power equipment field. Complimentary copies will be forwarded to interested engineers and executives, upon request.

Herbert Morris, Inc., Buffalo, has published an illustrated folder in which worm-gear chain blocks are described and illustrated. One illustration shows a 10-ton block lifting a load of 15 tons, the lifting being done by means of its own gears.

A. W. Cadman Mfg. Company, Pittsburgh, has published a 16-page illustrated

booklet in which bearing metals are described. The booklet contains interesting information including requirements of bearing metals, properties, tensile strength and bonding properties, etc.

Two bulletins under one cover are being circulated by the U. S. Galvanizing & Plating Equipment Corporation, New York, the first devoted to describing and illustrating moving cathode plating apparatus for plating or electric galvanizing, and the second to automatic cleaning, pickling, acid dip, neutralizing, rinsing, drying and allied equipment.

The Esterline-Angus Company, Indianapolis, is circulating a 4-page illustrated folder in which the use of graphic recording equipment is described. How engineers for the Milwaukee Coke & Gas Company maintained a continuous check on the performance of a gravity concrete mixing plant is told in the booklet as well as how graphic records taken in a Chicago office building showed why lighting bills were high.

The Thompson Electric Company, Cleveland, has published a 12-page illustrated folder in which disconnecting electric light hangers for use in industrial and other lighting, are described and illustrated. The booklet points out the waste caused through dirty reflectors as well as the dangers encountered by workmen in climbing to wash stationary lamps. With the aid of lamp hangers such dangers and waste can be eliminated. The lamps can be installed anywhere and easily lowered, in the latter operation the lamp disconnecting from the circuit leaving the wiring undisturbed. When pulled back into place again the lamp automatically goes back into the circuit and locks. A complete description of the hangers is given which is supplemented with illustrations and line drawings.

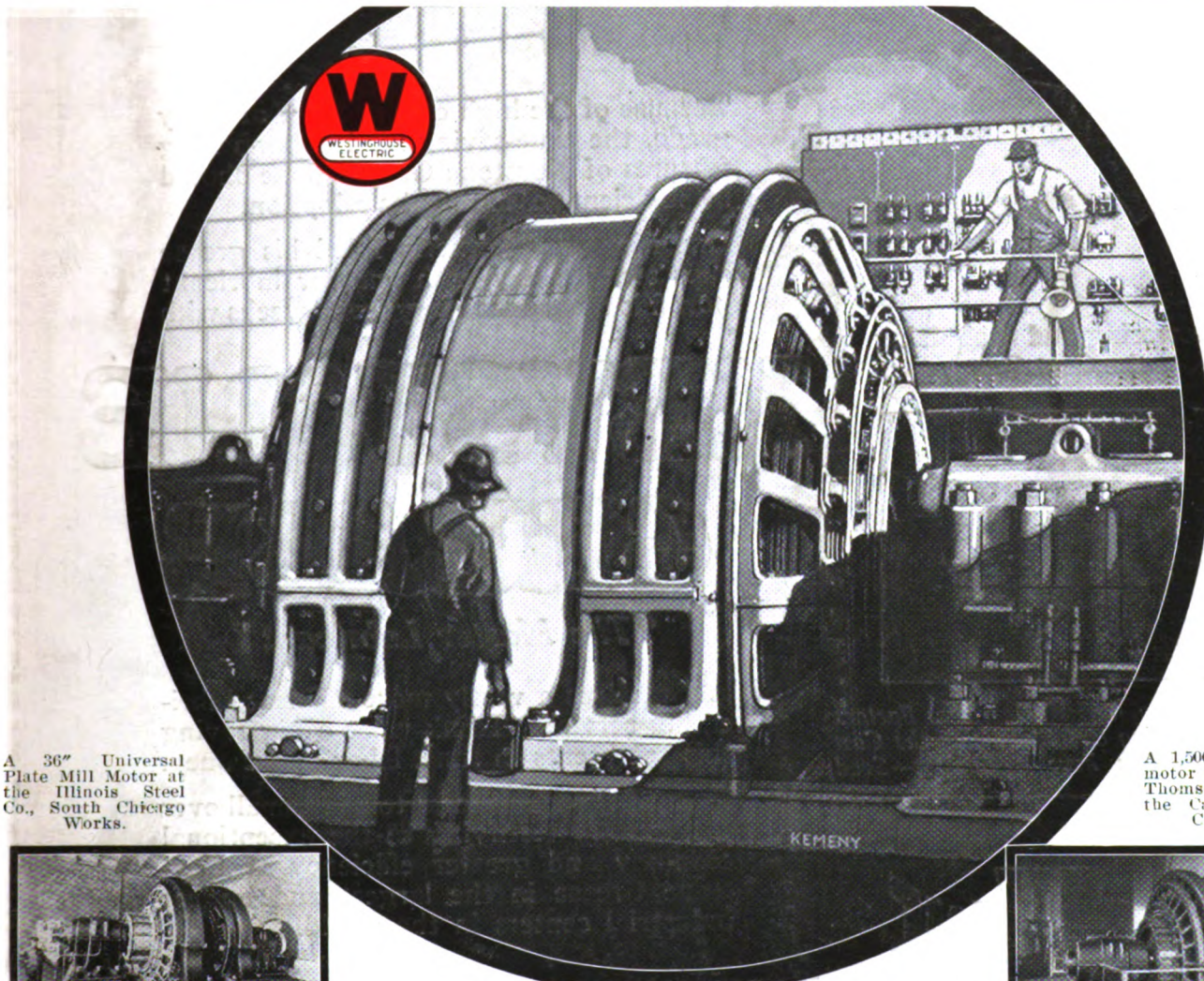
A power fed vertical hollow chisel mortiser is described and illustrated in a 4-page illustrated bulletin being circulated by the Oliver Machinery Company, Grand Rapids, Mich. This mortiser will handle chisels from 1/4-inch to 1 1/4-inch square. The stroke is adjustable from 2 1/2 inches to 4 inches long. Stock 6 inches wide can be centered beneath the chisel. Hollow chisels with 4-inch blades will mortise in 12-inch high material; chisels with 2 3/4-inch blades are commonly used in 1/2-inch and 5/16-inch sizes. The column is a rigid, hollow, box type, one piece casting having a wide flanged floor support. It encloses the power feed mechanism with the exception of the drive pulley. The ways for the chisel carriage and for the table are planed at one setting to insure accurate alignment. A fan blower built-in back of the column furnishes a constant air blast which cools the tools and keeps the work free from chips. A complete description of the tool is given.

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Member of the Audit Bureau of Circulations.



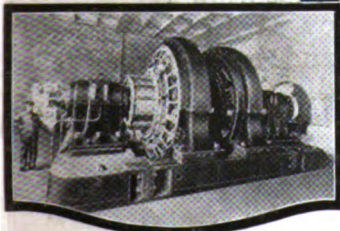
The Blast Furnace *and* Steel Plant

Pittsburgh, October, 1922.

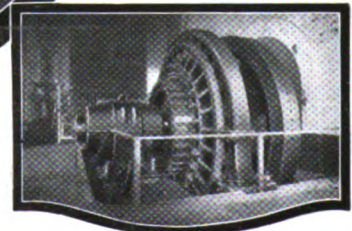


A 36" Universal Plate Mill Motor at the Illinois Steel Co., South Chicago Works.

A 1,500 hp., D. C., motor in the Edgar Thomson Works of the Carnegie Steel Company.



A view of the 15,000 hp., D. C., Westinghouse Motor which replaced a twin simple steam engine driving a 44" blooming mill at the Bethlehem Steel Company, Steelton, Pa.



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